"Condition Assessment of Buildings using Rapid Visual Screening Procedure"

A Major Project Report

Submitted in partial fulfilment of

MASTER OF TECHNOLOGY
in
STRUCTURAL ENGINEERING

Under the Guidance of
Dr. Alok Verma

Professor
(Department of Civil Engineering)

Submitted by
AKHILESH KUMAR CHAUDHARY
2K12/STE/026

DEPARTMENT OF CIVIL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
DELHI-110042

DELHI TECHNOLOGICAL UNIVERSITY
CERTIFICATE

This is to certify that the work presented in this thesis "**Condition Assessment of Buildings using Rapid Visual Screening Procedure**" by "**AKHILESH KUMAR CHADHARY**" **Roll No. 2K12/STE/026** in partial fulfilment of requirement for the award of degree of Master of technology in Structural Engineering submitted in the Department of Civil Engineering under my supervision in the session January to June 2018 at **DELHI TECHNOLOGICAL UNIVERSITY, DELHI**

Signature of the Supervisor:

Dr. Alok Verma
Professor
Department of Civil Engineering
Delhi Technological University
Dated: - 15/05/2018

ABSTRACT

With the occurrence of a number of earthquakes in the past and chances of many more in the future, seismic risk assessment has become a key factor in the seismic risk mitigation and management. Seismic design for structure has evolved with the passage of time and so has the complexity in design and construction.

Seismic design has its own limitation. Every types of structure deteriorate with time and become seismically vulnerable. Seismic vulnerability also depends upon the quality of construction and uses of structure. In a country like India where population is large, the number of building vulnerable to seismic condition present a difficult situation in regarding to life safety.

India is a developing country where construction work is increasing day by day very fast to cope up with the present growing requirement. Due to poor economical conditions many buildings are not in a good condition, hence a very rapid, reliable and economical method is required to roughly judge the seismic safety of buildings. Rapid Visual Screening of building structure appropriately serves the purpose.

In the present work, various aspects of Rapid Visual Screening (R.V.S.) are considered. Rapid visual screening practices in US as per FEMA 154 and those in India are studied and an overview of topic is developed. Later on efforts are made to devise a new more accurate and quicker R.V.S system for Indian conditions. This new RVS system is proposed in detail and explained. With the help of this RVS system the various building of BSES Yamuna Power LTD is screened and the Result obtained and compared.

ACKNOWLEDGEMENT

I would like to thank Prof.Alok Verma Department of civil engineering, DTU, Delhi, India for his generous help and useful suggestions. I would also like to express my gratitude to Dr. Nirendra Dev, H.O.D (Civil Engineering Department) DTU, Delhi.

Mr. Devender Sharma and Mr. Gaurav Sharma of CES Dept. BSES YPL Delhi, India for their helpful guidance, encouragement,support and supervision throughout the period of present work.

I am thankful to them for providing me their infrastructure facilities to complete this work as without their help this work would not have been possible.

AKHILESH KUMAR CHAUDHARY
Roll No.:- 2K12/STE/26
Department of Civil Engineering
Delhi Technological University
Delhi-110042

TABLE OF CONTENTS

Chapter 3: CASE STUDY AND SURVEY OF BSES YAMUNA POWER OFFICE BUILDING

List of Table **Page No.**

.

List of Figure **Page No.**

List of Graph **Page No.**

Chapter 1- INTRODUCTION

1.1 GENERAL

In the developing countries like India where population is increasing very fast the needs of building for residential, commercial and for other purpose increase exponentially. These increase in demand enhanced the rate of constructions of the building.

With the mass constructions of the buildings, it is a prerequisite to take special care of seismic safety at the design stage and during construction but in the country like India where corruption is a part of day to day life construction norms is not followed. Poor quality of material is used for the construction. Faulty and deteriorating structure is used prolonged. All contribute to the seismic vulnerability of the structure.

In construction economy plays a vital role so in seismic analysis its role cannot be ignored. In Indian situation one needs a very rapid, reliable and economically sounds process for risk assessment of building for seismic safety. RVS has been developed for this purpose and is quite useful.

RVS procedure for Indian conditions is still in its oversimplified preliminary stage and needs to be revived. Score system is incorporated as in FEEMA 154 with some modification. Speed enhanced by using computer technology.

1.2 OBJECTIVE OF PRESENT STUDY

1. Detailed study of various Rapid Visual Screening (RVS) methodologies proposed by various Indian researchers and building a common RVS procedure incorporating the features of all these researches which use a score system.

2. Further enhancing the accuracy of the above developed system by incorporating some new factors in the score system which affects the overall seismic safety of a building.

3. With this enhanced and speedy system performing **RVS of a particular no of building structure. (Say five)**

4. Making comparisons of the results obtained and drawing suitable inferences and conclusions**.**

1.3 SCOPE OF PRESENT STUDY

The expected result of this project would be a prototype system to a more developed, accurate and quick RVS methodology for Indian conditions which may be better than the current RVS methodology and a suitable computer program to execute the RVS process.

Thus it would facilitate checking the seismic vulnerability of building in India with a higher degree of precision and accuracy that too in a smaller time and in a simple manner.

With proper developments and improvements, the RVS system under this project could possibly serve as a base for a totally new Integrated Rapid visual screening system in India as currently exist in US and other countries.

1.4 METHODOLOGY-

The methodology for the project can easily explained by the following flow chart-

RVS PROJECT STAGES

1. BUILDING KNOWLEDGE BASE
2. FOR ACCURACY
3. FOR SPEED
4. PRACTICAL FIELD APPLICATION

STAGE 1

- STUDY OF VARIOUS METHEDOLOGY AND PROCEDURE DEVELOPED FOR RVS IN INDIAN CONDATION.

STAGE 2

- DEVELOPING A RVS SYSTEM (BASED ON SCORE METHOD) INCORPORATING NEW FACTOR WHICH MODIFY SEISMIC SAFETY.

STAGE 3

- DEVELOVING A USER FRIENDLY AND SPEEDIER USER FRIENDLY MS EXCEL PROGRAM FOR NEW RVS SYSTEM DEVELOPED IN STAGE 2. RVS SYSTEM SPECIFIED IN IS CODE**.**

STAGE 4

- RVS OF A PARTICLAR NO OF BUILDING OF BSES YPL.

STAGE 5

- MAKING COMPERISION, RESULT AND CONCLUSION.

2.1 RAPID VISUALN SCREENING (RVS) DEFINITION

"Rapid visual screening or site walk survey is a procedure of visual inspection of a particular building or group or group of buildings of same type so as to identify the presence of basic structural anomalies and environmental damages which that building has faced during the span of time, recording these observation and thus commenting on the seismic and overall safety of the building or group of buildings."

It is only a visual screening method no testing is carried out to know the risk assessment of building. It is a rapid and quick assessment process.

2.2 **NEED FOR RAPID VISUAL SCREENING SYSTEM**

It is a first basic fundamental of building for the assessment risk parameter and its need cannot be overlooked.

It is needed for the analysis of a particular building whether it requires further analysis for seismic vulnerability or not.

It is required to assess the damage due to seismic force and rehabilitation need.

RVS system is quick and cost effective. It can be implicated firstly with low cost and after knowing the hazardous condition of building further seismic analysis test can be carried out.

2.3 RESERCH AND DEVDELOPMENT.

Rapid visual screening is not a new methodology; it is being used since long time when ancient people use the expertise of those people who is having the knowledge in construction field to inspect the old building for renovation.

The modern RVS was originally developed by the FEMA (FEDRAL EMERGENCY MANAGEMENT AGENCY) OF THE UNITED STATES DEPARTMENT of Homeland security. A potential seismic hazard via rapid visual screening of building was developed in 1988 which was reported in FEMA 154.

After the publication of FEMA 154 handbook RVS technique was used by private sector organisations and govt. agencies for the evaluation of buildings in various countries.

Later on after a decade a revised second edition of FEMA 154 was published in 2002. The 2002 edition of FEMA 154 report on RVS technique retained same frame work and approach as in previous FEMA report but the only change was in scoring system compatibility with ground motion criteria of FEMA 310 report, Handbook on seismic evaluation of building.

RVS was incorporated in annexure A clause 7 of IS 13935-2009 “Indian slandered seismic evaluation, reapir and strengthening of masonry building guidelines”.

2.4 RAPID VISUAL SCREENING AS FEEMA NORMS

2.4.1 OVERVIEW

The FEEMA methodology of Rapid visual screening is based on structural score method.

In this system each structure is assigned a basic score based on the type of structure. FEEMA classifies 15 types of structure. The person who carries the RVS has to match the building with these 15 types. The screener gets the basic score of the building to screen.

After that FEEMA 154 specifies some parameter called score modifier . These are in fact the factors which affects the seismic performance of structure like irregularities, soil type etc. Each factor is assigned a score which modifies the basic score of structure called score modifier.

The observer notes the basic score and the score modifier by visual inspection of the structure. This record is mentioned in the RVS form of FEEMA 154 along with other detail of structure like sketch, photograph, location, occupancy and uses etc. The algebraic sum of basic score and modifier gives the overall structural score. If the overall score is less than the cut off score then the structure is unsafe and it is proposed to carry out the detailed seismic analysis of structure to mark safe.

Determining the cut off score is the most important parameter in this method generally a score of 2 or 3 is adopted depending upon the frequency and severity of earthquake, but observer is free to choose any value depending upon the use and importance of building. Lower is the value of cut off score higher is the safety criteria and higher is the score value better is the economy criteria.

On the basis of these observation screener concludes whether the structure is safe or not and suggest the repairing and retrofitting methods.

2.4.2. RVS PROCEDURE OUTLINE

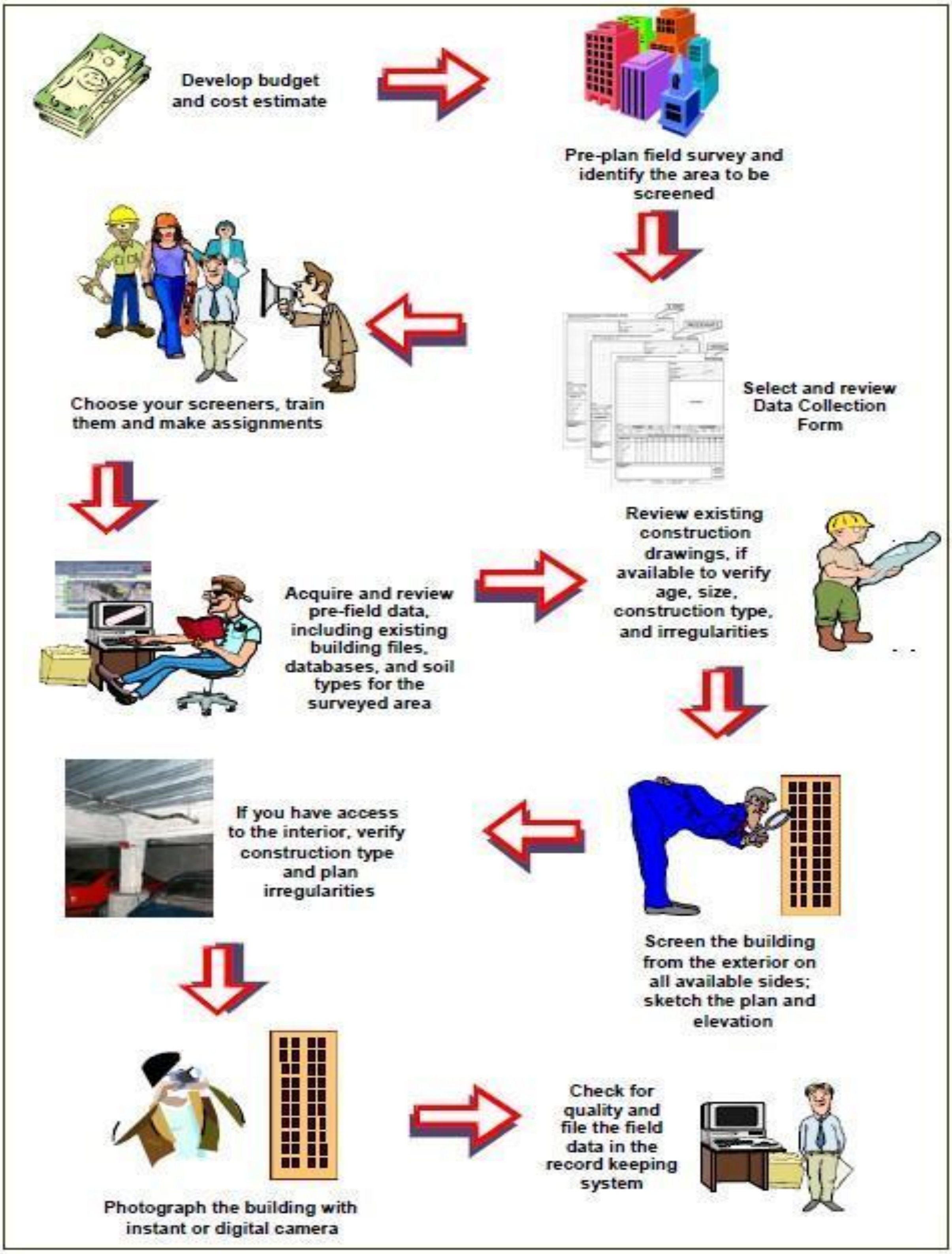


Fig.1:- A flow chart showing the steps involved in RVS implementation sequence

2.4.3 BASIC STRUCTURE TYPE AND THEIR BEHAVIOUR

As per second edition of FEMA 154(2002) fifteen types of building are used in RVS procedure. Reference code is described below.

1. W1= Light wood frame for residential and commercial buildings of size less than or equal to 5000 square feet.
2. W2= Light wood frame buildings larger than 5000 square feet.
3. S1= Moment resisting frame building of steel structure.
4. S2= Braced frame steel structure buildings.
5. S3= Light metal buildings.
6. S4= Steel frame buildings with cast in situ shear wall of concrete.
7. S5= Steel frame buildings with masonry infill walls without reinforcement.
8. C1= Moment resisting frame building of concrete.
9. C2= Shear wall concrete building.
10. C3= Concrete frame with masonry wall without reinforcement.
11. PC1= Tilt up buildings.
12. PC2= Concrete frame buildings of precast structure.
13. RM1=Reinforced masonry buildings with flexible floor and roof.
14. RM2= Reinforced masonry building with rigid floor and roof.
15. URM= Load bearing wall buildings with unreinforced masonry building.

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
W1 Light wood frame residential and commercial buildings equal to or smaller than 5,000 square feet		H = 2.8 M = 5.2 L = 7.4	• Wood stud walls are typically constructed of 2-inch by 4-inch vertical wood members set about 16 inches apart (2-inch by 6-inch for multiple stories). • Most common exterior finish materials are wood siding, metal siding, or stucco. • Buildings of this type performed very well in past earthquakes due to inherent qualities of the structural system and because they are lightweight and low rise. • Earthquake-induced cracks in the plaster and stucco (if any) may appear, but are classified as non-structural damage. • The most common type of structural damage in older buildings results from a lack of connection between the superstructure and the foundation, and inadequate chimney support.
W2 Light wood frame buildings greater than 5,000 square feet		H = 3.8 M =4.8 L = 6.0	• These are large apartment buildings, commercial buildings or industrial structures usually of one to three stories, and, rarely, as tall as six stories.

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S1 Steel moment-resisting frame		H = 2.8 M = 3.6 L = 4.6	• Typical steel moment-resisting frame structures usually have similar bay widths in both the transverse and longitudinal directions, around 20-30 ft. • The floor diaphragms are usually concrete, sometimes over steel decking. This structural type is used for commercial, institutional and public buildings. • The 1994 Northridge and 1995 Kobe earthquakes showed that the welds in steel moment- frame buildings were vulnerable to severe damage. The damage took the form of broken connections between the beams and columns.
S2 Braced steel frame	  Zoom-in of upper photo	H = 3.0 M = 3.6 L = 4.8	• These buildings are braced with diagonal members, which usually cannot be detected from the building exterior. • Braced frames are sometimes used for long and narrow buildings because of their stiffness. • From the building exterior, it is difficult to tell the difference between steel moment frames, steel braced frames, and steel frames with interior concrete shear walls. • In recent earthquakes, braced frames were found to have damage to brace connections, especially at the lower levels.

Fig.2:- Types of building codes with hazard score and its earthquake history

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S3 Light metal building		H = 3.2 M = 3.8 L = 4.6	• The structural system usually consists of moment frames in the transverse direction and braced frames in the longitudinal direction, with corrugated sheet-metal siding. In some regions, light metal buildings may have partial-height masonry walls. • The interiors of most of these buildings do not have interior finishes and their structural skeleton can be seen easily. • Insufficient capacity of tension braces can lead to their elongation and consequent building damage during earthquakes. • Inadequate connection to a slab foundation can allow the building columns to slide on the slab. • Loss of the cladding can occur.
S4 Steel frames with cast-in-place concrete shear walls		H = 2.8 M = 3.6 L = 4.8	• Lateral loads are resisted by shear walls, which usually surround elevator cores and stairwells, and are covered by finish materials. • An interior investigation will permit a wall thickness check. More than six inches in thickness usually indicates a concrete wall. • Shear cracking and distress can occur around openings in concrete shear walls during earthquakes. • Wall construction joints can be weak planes, resulting in wall shear failure below expected capacity.

Building Identifier	Photograph	Basic Structural Hazard Score	Characteristics and Performance
S5 Steel frames with unreinforced masonry infill walls		H = 2.0 M = 3.6 L = 5.0	• Steel columns are relatively thin and may be hidden in walls. • Usually masonry is exposed on exterior with narrow piers (less than 4 ft wide) between windows. • Portions of solid walls will align vertically. • Infill walls are usually two to three wythes thick. • Veneer masonry around columns or beams is usually poorly anchored and detaches easily.
C1 Concrete moment-resisting frames		H = 2.5 M = 3.0 L = 4.4	• All exposed concrete frames are reinforced concrete (not steel frames encased in concrete). • A fundamental factor governing the performance of concrete moment-resisting frames is the level of ductile detailing. • Large spacing of ties in columns can lead to a lack of concrete confinement and shear failure. • Lack of continuous beam reinforcement can result in hinge formation during load reversal. • The relatively low stiffness of the frame can lead to substantial nonstructural damage. • Column damage due to pounding with adjacent buildings can occur.

Building Identifier	Photograph	Basic Structural Hazard Score	Characteristics and Performance
PC1 Tilt-up buildings	  Partial roof collapse due to failed diaphragm-to-wall connection	H = 2.6 M = 3.2 L = 4.4	• Tilt-ups are typically one or two stories high and are basically rectangular in plan. • Exterior walls were traditionally formed and cast on the ground adjacent to their final position, and then "tilted-up" and attached to the floor slab. • The roof can be a plywood diaphragm carried on wood purlins and glulam beams or a light steel deck and joist system, supported in the interior of the building on steel pipe columns. • Weak diaphragm-to-wall anchorage results in the wall panels falling and the collapse of the supported diaphragm (or roof).

Building Identifier	Photograph	Basic Structural Hazard Score	Characteristics and Performance
C2 Concrete shear wall buildings		H = 2.8 M = 3.6 L = 4.8	• Concrete shear-wall buildings are usually cast in place, and show typical signs of cast-in-place concrete. • Shear-wall thickness ranges from 6 to 10 inches. • These buildings generally perform better than concrete frame buildings. • They are heavier than steel-frame buildings but more rigid due to the shear walls. • Damage commonly observed in taller buildings is caused by vertical discontinuities, pounding, and irregular configuration.
C3 Concrete frames with unreinforced masonry infill walls		H =1.6 M = 3.2 L = 4.4	• Concrete columns and beams may be full wall thickness and may be exposed for viewing on the sides and rear of the building. • Usually masonry is exposed on the exterior with narrow piers (less than 4 ft wide) between windows. • Portions of solid walls will align vertically. • This type of construction was generally built before 1940 in high-seismicity regions but continues to be built in other regions. • Infill walls tend to buckle and fall out-of-plane when subjected to strong lateral out-of-plane forces. • Veneer masonry around columns or beams is usually poorly anchored and detaches easily.

Fig.3:- Types of building codes with hazard score and its earthquake history

Building Identifier	Photograph	Basic Structural Hazard Score	Characteristics and Performance
PC2 Precast concrete frame buildings	 Building under construction  Detail of the precast components  Building nearing completion	H = 2.4 M = 3.2 L = 4.6	• Precast concrete frames are, in essence, post and beam construction in concrete. • Structures often employ concrete or reinforced masonry (brick or block) shear walls. • The performance varies widely and is sometimes poor. • They experience the same types of damage as shear wall buildings (C2). • Poorly designed connections between prefabricated elements can fail. • Loss of vertical support can occur due to inadequate bearing area and insufficient connection between floor elements and columns. • Corrosion of metal connectors between prefabricated elements can occur.

Fig.4:- Types of building codes with hazard score and its earthquake history

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
RM1 Reinforced masonry buildings with flexible dia-phragms	  Truss-joists support plywood and light-weight concrete slab  Detail showing reinforced masonry	H = 2.8 M = 3.6 L = 4.8	• Walls are either brick or con-crete block. • Wall thickness is usually 8 inches to 12 inches. • Interior inspection is required to determine if diaphragms are flexible or rigid. • The most common floor and roof systems are wood, light steel, or precast concrete. • These buildings can perform well in moderate earthquakes if they are adequately rein-forced and grouted, with suffi-cient diaphragm anchorage. • Poor construction practice can result in ungrouted and unre-inforced walls, which will fail easily.

Fig.5:- Types of building codes with hazard score and its earthquake history

Building Identifier	Photograph	Basic Structural Hazard Score	Characteristics and Performance
RM2 Reinforced masonry buildings with rigid dia-phrams		H = 2.8 M = 3.4 L = 4.6	• Walls are either brick or con-crete block. • Wall thickness is usually 8 inches to 12 inches. • Interior inspection is required to determine if diaphragms are flexible or rigid. • The most common floor and roof systems are wood, light steel, or precast concrete. • These buildings can perform well in moderate earthquakes if they are adequately rein-forced and grouted, with suffi-cient diaphragm anchorage. • Poor construction practice can result in ungrouted and unre-inforced walls, which will fail easily.
URM Unreinforced masonry buildings		H = 1.8 M = 3.4 L = 4.6	• These buildings often used weak lime mortar to bond the masonry units together. • Arches are often an architec-tural characteristic of older brick bearing wall buildings. • Other methods of spanning are also used, including steel and stone lintels. • Unreinforced masonry usu-ally shows header bricks in the wall surface. • The performance of this type of construction is poor due to lack of anchorage of walls to floors and roof, soft mortar, and narrow piers between window openings.

Fig.6:- Types of building codes with hazard score and its earthquake history

2.4.4. DATA COLLECTION FORMS*[1] (AS PER FEMA 154(2002))

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

LOW Seismicity

Scale:

Address: ______________________________

______________________ **Zip** __________

Other Identifiers ______________________

No. Stories ____________________ **Year Built** ________

Screener ____________________ **Date** ____________

Total Floor Area (sq. ft.) ______________________

Building Name ______________________

Use ______________________

PHOTOGRAPH

OCCUPANCY			**SOIL**	**TYPE**						**FALLING HAZARDS**			
Assembly Commercial Emer. Services	Govt Historic Industrial	Office Residential School	Number of Persons 0 – 10 11 – 100 101-1000 1000+	A Hard Rock	B Avg. Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	☐ Unreinforced Chimneys	☐ Parapets	☐ Cladding	☐ Other: ______

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**7.4**	**6.0**	**4.6**	**4.8**	**4.6**	**4.8**	**5.0**	**4.4**	**4.8**	**4.4**	**4.4**	**4.6**	**4.8**	**4.6**	**4.6**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.2	-0.2	+0.4	-0.2	-0.4	N/A	-0.2	-0.4	-0.2	-0.6
High Rise (>7 stories)	N/A	N/A	+1.0	+1.0	N/A	+1.0	+1.2	+1.0	0.0	-0.4	N/A	-0.2	N/A	0.0	N/A
Vertical Irregularity	-4.0	-3.0	-2.0	-2.0	N/A	-2.0	-2.0	-1.5	-2.0	-2.0	N/A	-1.5	-2.0	-1.5	-1.5
Plan Irregularity	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8
Pre-Code	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Post-Benchmark	0.0	+0.2	+0.4	+0.6	N/A	+0.6	N/A	+0.6	+0.4	N/A	+0.2	N/A	+0.2	+0.4	+0.4
Soil Type C	-0.4	-0.4	-0.8	-0.4	-0.4	-0.4	-0.4	-0.6	-0.4	-0.4	-0.4	-0.2	-0.4	-0.2	-0.4
Soil Type D	-1.0	-0.8	-1.4	-1.2	-1.0	-1.4	-0.8	-1.4	-0.8	-0.8	-0.8	-1.0	-0.8	-0.8	-0.8
Soil Type E	-1.8	-2.0	-2.0	-2.0	-2.0	-2.2	-2.0	-2.0	-2.0	-2.0	-1.8	-2.0	-1.4	-1.6	-1.4

FINAL SCORE, *S*

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

2.4.5 FORMS DETAILS AND SCORE MODIFIERS (FEMA 154(2002))

Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154)

Quick Reference Guide (for use with Data Collection Form)

1. Model Building Types and Critical Code Adoption and Enforcement Dates

Structural Types		Year Seismic Codes Initially Adopted and Enforced*	Benchmark Year when Codes Improved
W1	Light wood frame, residential or commercial, ≤ 5000 square feet	_______	_______
W2	Wood frame buildings, > 5000 square feet.	_______	_______
S1	Steel moment-resisting frame	_______	_______
S2	Steel braced frame	_______	_______
S3	Light metal frame	_______	_______
S4	Steel frame with cast-in-place concrete shear walls	_______	_______
S5	Steel frame with unreinforced masonry infill	_______	_______
C1	Concrete moment-resisting frame	_______	_______
C2	Concrete shear wall	_______	_______
C3	Concrete frame with unreinforced masonry infill	_______	_______
PC1	Tilt-up construction	_______	_______
PC2	Precast concrete frame	_______	_______
RM1	Reinforced masonry with flexible floor and roof diaphragms	_______	_______
RM2	Reinforced masonry with rigid diaphragms	_______	_______
URM	Unreinforced masonry bearing-wall buildings	_______	_______

*Not applicable in regions of low seismicity

2. Anchorage of Heavy Cladding

Year in which seismic anchorage requirements were adopted: _______

3. Occupancy Loads

Use	Square Feet, Per Person	Use	Square Feet, Per Person
Assembly	varies, 10 minimum	Industrial	200-500
Commercial	50-200	Office	100-200
Emergency Services	100	Residential	100-300
Government	100-200	School	50-100

4. Score Modifier Definitions

Mid-Rise:	4 to 7 stories
High-Rise:	8 or more stories
Vertical Irregularity:	Steps in elevation view; inclined walls; building on hill; soft story (e.g., house over garage); building with short columns; unbraced cripple walls.
Plan Irregularity	Buildings with re-entrant corners (L, T, U, E, + or other irregular building plan); buildings with good lateral resistance in one direction but not in the other direction; eccentric stiffness in plan, (e.g. corner building, or wedge-shaped building, with one or two solid walls and all other walls open).
Pre-Code:	Building designed and constructed prior to the year in which seismic codes were first adopted and enforced in the jurisdiction; use years specified above in Item 1; default is 1941, except for PC1, which is 1973.
Post-Benchmark:	Building designed and constructed after significant improvements in seismic code requirements (e.g., ductile detailing) were adopted and enforced; the benchmark year when codes improved may be different for each building type and jurisdiction; use years specified above in Item 1 (see Table 2-2 of FEMA 154 *Handbook* for additional information).
Soil Type C:	Soft rock or very dense soil; S-wave velocity: 1200 – 2500 ft/s; blow count > 50; or undrained shear strength > 2000 psf.
Soil Type D:	Stiff soil; S-wave velocity: 600 – 1200 ft/s; blow count: 15 – 50; or undrained shear strength: 1000 – 2000 psf.
Soil Type E:	Soft soil; S-wave velocity < 600 ft/s; or more than 100 ft of soil with plasticity index > 20, water content > 40%, and undrained shear strength < 500 psf.

2.4.6 DETERMINATION OF BASIC STRUCTURAL SCORE AND SCORE MODIFIER VALUES

The basic structural score in FEMA 154 methodology is defined as negative of logarithm (base 10) of the probability of collapse of the building, given the ground motion corresponding to maximum possible earthquake (MCE). Denoted as

BASIC STRUCTURE SCORE = -log10[P (FAILUARE AT MAXIMUM CONSIDERED EARTHQUAKE)]

Where BSH = Basic structural score and MCE = Maximum considered earthquake.

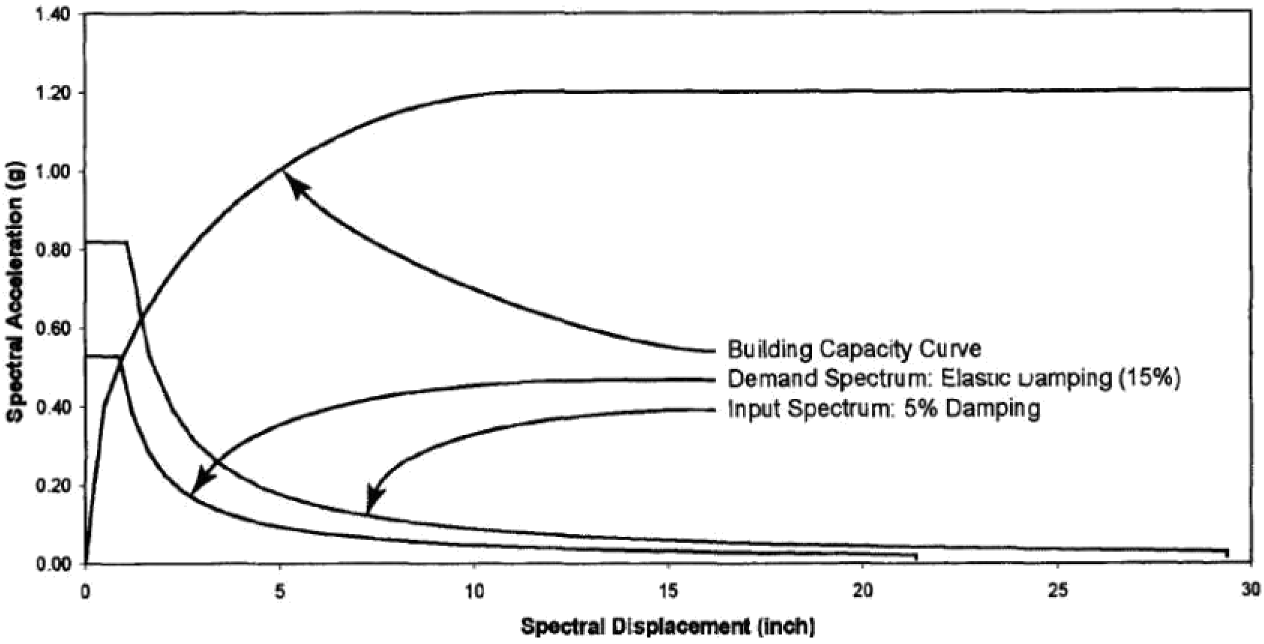
Earlier the 1st edition of FEMA 154 (1984) P as probability of 60% or more damage but it was later improvised in 2nd edition FEMA 154 (2002) which defined P as probability of collapse.

The basic structure score is a generic score for a particular type and class of buildings and it is modified for a particular building by score modifier relevant to that building to obtain a final structural score.

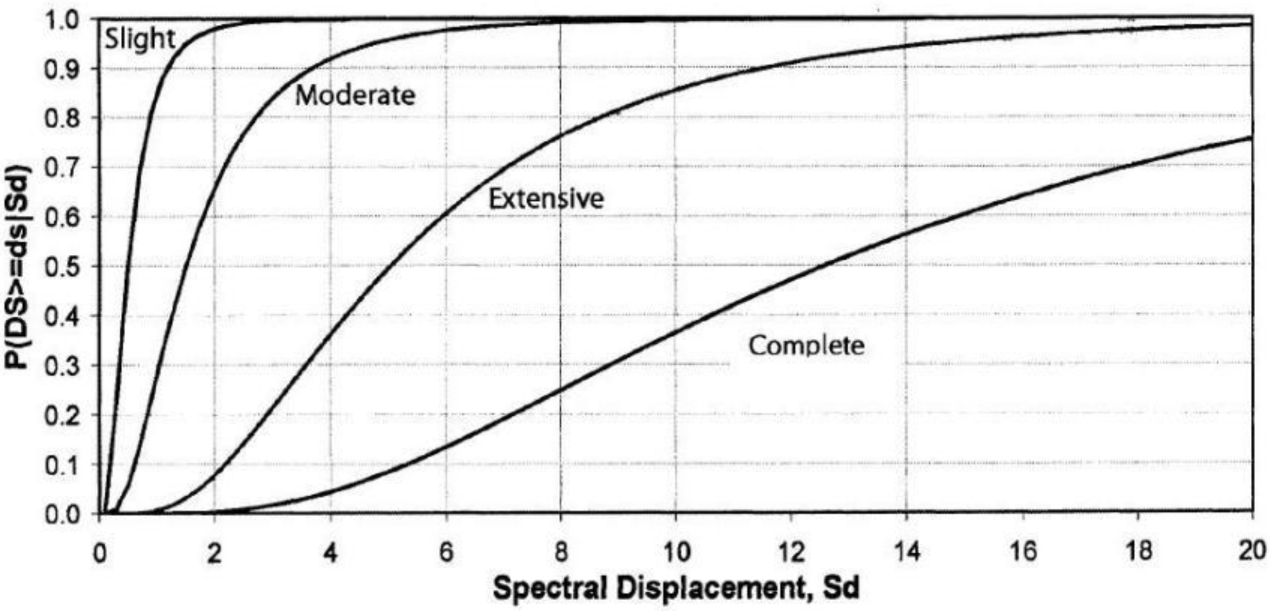
Score= Basic structure score +/- score modifier

The final score of a building is the final probability of failure of a building. If the final score(S) of a building is 2, it means the probability of failure of the building is 1 in 10^2 means 1 in 100.

Details of how these curves are used to determine BSHs and SMs are specified in HAZUS technical manual (NIBS 1999) and FEMA 155.



Graph 1:- Demand spectrum with input and demand spectrum with 15% elastic damping and typical capacity curve. (NIBS 1999)



Graph 2:- Fragility curves HAZUS99 (For W1 wood frame buildings) It shows the probability of damage state exceeded for the given level of ground shaking (NIBS 1999)

2.4.7. DETERMINING THE CUTOFF SCORE:

"Rapid visual screening (RVS) **structural cut off score (cut off S) is decided on the basis of relative importance of "cost of safety" v/s "benefit".**

The cost of safety includes:

- Cost of investigation of no. of buildings (no. can be in hundreds or thousands) and base on data collected during investigation reviewing in detail to find those areas of structure which can be damaged due to major earthquake.
- Rehabilitation cost for buildings or part of building which are weak under major earthquake.

The benefit of cut-off score is the life can be saved and injuries can be prevented by rehabilitating the life from dangerous structures.

Every community and authority is free to choose its cut off score depending upon to which factor it gives more importance, cost of safety or benefits.

As per national bureau of standards (NBC) of US (1980) And SAC (2000), value of cut-off score of three is safe for day to day loading But value less than 3 is irregular or threat for earthquake.

To differentiate between adequate and inadequate structure the score value of two is reasonable in contest of RVC. Inadequate structure requires detail review if score value is used is higher than two then it implies that greater safety is required.

2.5 RAPID VISUAL SCREENING (RVS) FOR INDIAN CONDITION

2.5.1 OVERVIEW:

The FEMA methodology of rapid visual screening is not exactly suitable for Indian conditions in its original form. The reason behind this is that India is a diversified country with construction practices ranging from highly urban construction comprising of modular steel and RCC structure to basic mud to earthen structures in villages. Hence only some not all structure type mentioned in FEMA 154 can be associated with Indian structures. Moreover the size and occupancy and construction practices used to build these structures also has their own influence. The seismicity variation in India also cannot be overlooked. Thus we need a somewhat different methodology for RVS as per Indian conditions.

Rapid visual screening (RVS) for Indian condition as specified in IS 13935: 2099 is based on a **"logical system"** rather than a "structural score system" as in FEMA 154.

In this system 6 building types are mentioned (A to F) in which some types (C and D) is common for both masonry and RCC/steel frame structures. + sign is used to specify slightly more seismic strength or lower seismic vulnerability. Five damageability grades (G1 to G5) are also specified separately for masonry and RCC/steel frame structures. Based on the type of structure and its location in the particular seismic zone (zone 2 to zone 5), the damage which it can undergo is specified in the form of table. Moreover some other parameters like falling hazard, special hazard, URM infills and special observation are specified.

Bases on the parameters and the types of structure and seismic zone the observer and screener can identified the damage which the structure can undergo (in case of damageability grade G) and remedial measures that could be done for its prevention all this is recorded.

2.5.2 SEISMIC ZONE IN INDIA *[14]:

IS 1893:2002(PART1) divides country in four seismic zones.

ZONE II: low seismic hazard (earthquake magnititude intensity lower than or equal to 6)
ZONE III: Moderate seismic hazard (earthquake magnititude intensity lower than or equal to 7)
ZONE IV: High seismic hazard (earthquake magnititude intensity lower than or equal to 8)

ZONE V: Very high seismic hazard (earthquake magnititude intensity greater than or equal to 9)

All four hazard zones are considered for the study of RVS system.

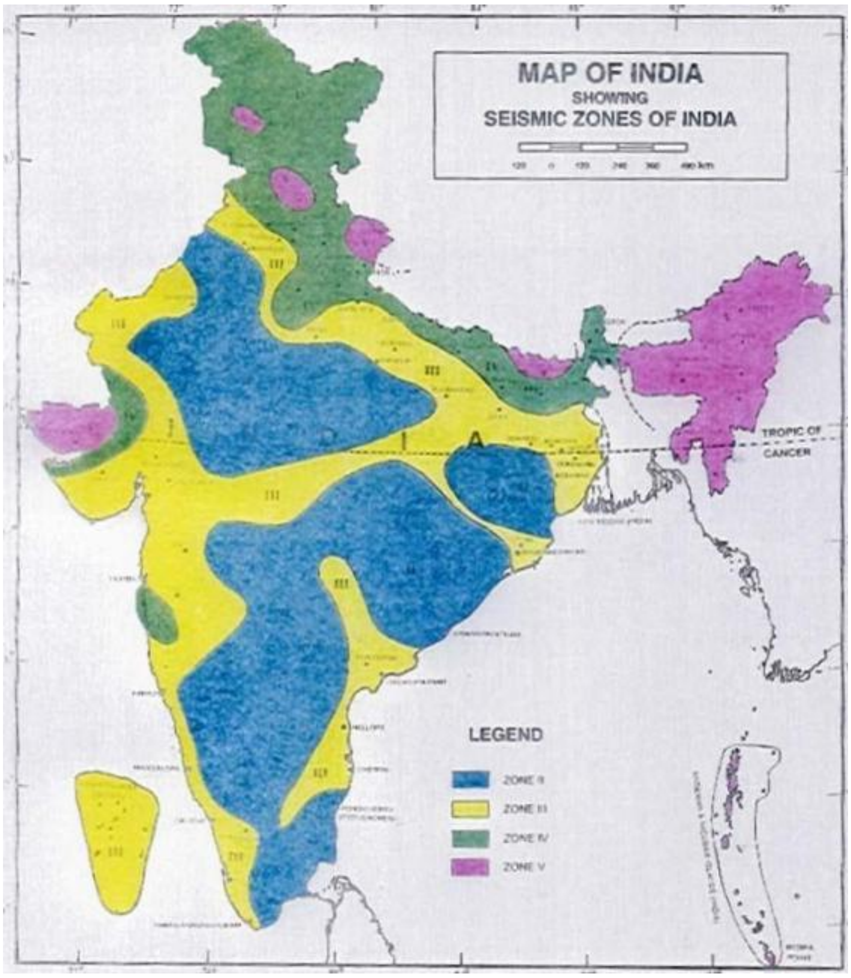


Fig.7:- Seismic Zones in India as per IS: 1893-2002

2.5.3 STRUCTURE TYPE FOR RVS AS PER INDIAN CONDITIONS:

Various types of construction practice and different types of material are used across the country in urban and rural area. Material used in the construction is locally available material or semi engineered or factory made material like steel, cement etc.

The seismic vulnerability of a building depends upon the choice of material used and construction practice adopted. The seismic hazard is highest with the locally available material used building and lower with the use of semi engineered or engineered material made in factory and engineering inputs. The vulnerability class of building is determined by the seismic performance during.

All structure has been divided into 6 types: Type A to Type F based on European macro seismic scale (EMS-98) recommendations. Type A structure have heigh risk and Type F have Low risk.

A structure of a given type may have its seismic vulnerability different from their basic class of structure depending upon the condition of the structure, presence of earthquake resistance feature,acrhitural feature, number of story etc.Some variation in the structure type is defined as A,B,B+ etc.

Table 1:- Classification of Masonry Structure for RVS

Building Type	Description
A	1. Rubble or stone with mud mortar or without mortar usually with sloping wooden roof. 2. Stone masonry uncrossed without adequate through stone'. 3. Round stone masonry.
B	Semi dressed stone bought to courses with through stone and corner long stones, Unreinforced brick walls with country type wooden roof; Unreinforced CC blocks wall construction in mud mortar or in lime mortar.
B+	1) Unreinforced brick masonry in mud mortar with vertical wood post or horizontal wood elements or seismic band(IS:13828) 2) Unreinforced brick masonry in lime mortar.
C	1) Unreinforced masonry walls built from fully dressed stone masonry or CC block or burnt brick using good cement mortar. 2) Horizontal seismic band(IS13828)
C+	Horizontal seismic band at lintel level of door and window.
D	Reinforced with bands and vertical reinforcement (IS4326).

TABLE 2: Classification of RCC/Steel Frame Structures for RVS

Building TYPE	**Description**
C	A) Reinforced concrete beam post structure without ERD or WRD built in non-engineered way. B) SF without bracings having hinge joints. C) RCF of ordinary design for gravity loads without ERD or WRD. D) SF of ordinary design without ERD orWRD.
C+	A) MR-SF/MR-RCF of normal design without ERD or WRD. B) Masonry infill unreinforced. C) Framed structure with flat slab. D) Framed prefabricated structure.
D	A) MR-RCF with normal ERD without special details (IS:13920) B) MR-RCF with normal ERD without special details as per plastic design handbook.
E	A) MR-RCF with High level of ERD (IS:1893-2002) and special detail(IS:13920). B) MR-RCF with High level of ERD (IS:1893-2002) and special detail as per plastic design handbook, SP:6(6)-1972
E+	A) MR-RCF at E with proper designed infill walls. B) MMR-RCF at E with proper designed braces.
F	A) MR-RCF as at E with designed and detail RC shear wall. B) MR-RCF as at E with designed and detail steel braces and cladding. C) MR-RCF base isolation.

2.5.4 DAMAGE CLASSIFICATION AS PER INDIAN CONDITIONS:

Table 3:- Classification of damage in masonry building.

Classification of damage in masonry buildings
Grade 1:Slight or negligible damage (structural damage nil, minor non-structural damage) Structural: Hair-line crack found in very few walls. Non-structural: Small patch of plaster may fall. In little case loose stone or sand may fall from up stair.
Grade 2: Medium damage (minor structural damage, medium non-structural damage) structural: Cracks found in walls, thin cracks in RC slab Non-structural: Large pieces of plaster fall, Smoke chimney on roof get damage. Parapets, chajjas damaged .Roof may get damaged up to 10 %, may tilt.
Grade 3:Substanttial to major damage (average structure damage, major non-structural damage) Structural: Major and deep crack in all walls. Cracks in column and pier spread out. Non-structural: Tiles in roof detach, chimney fracture at roof, single non-structural elements fail.
Grade 4 : Severe Damage (major structure damage, severe non-structural damage) Structural: Major failure in walls (gap in wall), inner partition collapse , partial structural failure of roof and floor.
Grade 5 : Destruction(Total damage to structure) **Total failure of structure system**

Table 4:- Classification of damage in buildings of reinforced concrete

Classification of damage in buildings of reinforced concrete
Grade 1:Slight or negligible damage (structural damage nil, minor non-structural damage) Minor cracks in plaster over rigid member or in wall at the base. Minor cracks in partition and in between wall.
Grade 2: Medium damage (minor structural damage, medium non-structural damage). Minor cracks in beams and column of frame structure and in structural walls. Plaster falls. Mortar falls from joint.
Grade 3:Substanttial to major damage (average structure damage, major non-structural damage) Cracks mainly found in column and beam column joints of frames at the base and the joins of coupled walls. Concrete cover damage. Steel rod buckles.
Grade 4 : Severe Damage (major structure damage, severe non-structural damage) Major cracks in structural elements with compression failure of concrete. Steel bar fractures. Few column collapse , upper floor roof collapse
Grade 5 : Destruction(Total damage to structure) **Total failure of structure system**.

CHAPTER 3: CASE STUDY AND SURVEY OF BSES YAMUNA POWER OFFICE BUILDING

3.1 INTRODUCTION

There are many old building in India whose strength has reduced considerably with passage of time. If further use is continued it may be dangerous for the life occupant's and surrounding habitation. Necessary action must be taken to improve the performance of such structures and restore the desired strength and stability so that there is no risk on the safety of its occupants and critical use or function of the buildings or its components, equipments etc. So it is required to conduct the structural audit and necessary repair and maintenance work, by which the safety of occupants and life of structure increases.

All the municipal corporation in the country must make the structural audit of building compulsory after a life span of 30 year. The audit report must indicate the critical area of the building and remedial measures to prevent any mishappening. If necessary audit report must focus on the detail analysis of the building. Audit report must provide the cost effective solution.

In this present study we considered the visual inspection of the office building of BSES Yamuna power LTD. Govt. of Delhi and the need of non-destructive testing. In this study it is also emphasized on different repairs and retrofitting measures to be used for building after structural audit.

3.2 Guidelines for evaluating existing structures.

Evaluation of present structure is an important topic for experts working in construction in most industrial countries, where rehabilitation including repairs and upgrading of construction works represent about half of all construction activities. It is due to several circumstances including following items.

Existing structures represent substantial, continually increasing economic contribution. Users are interested in a new way of exploitation of existing structures. Many existing structures do not fulfil requirements of currently valid standards.

An Indian standard for the evaluation and retrofitting of present building structure has not been developed yet. Assessment of existing structures often requires knowledge overlapping the framework of standards for structure design. Assessment should be focused on minimal construction interventions to existing structures. Civil engineers, owners and representatives of governmental authorities need new guidance for the evaluation of existing structures.

Presently, latest Indian Standard has been implemented for the design of new structures. The earlier National Standards for structural design are withdrawn or revised in order to harmonize national prescriptive documents in all member states with respect to requirements of ISO and BIS standards.

Internationally, Euro codes serve mainly for the new structure design. They have not introduced provisions explicitly for evaluatio of existing structures and for design of repairs or up gradation till now. For this purpose, the international standard ISO 13822, FEMA guidelines, guidelines as prescribed by NDMA and CPWD, 'Handbook of seismic retrofit of buildings' based on the same principles as BIS is intended to be taken as the basis of this study, and this may be supplemented by national provisions based on practice of regional construction industry.

3.3 Structural Audit

It is an overall health and performance checking of a building .It certifies that the building and its surrounding is safe and have no risk of life. In structure audit building is analysed and suggested appropriate repair and retrofitting measures. Structural audit is being carried out by the experienced and licensed structural consultant.

Purpose of Structural Audit

- To save the life and structure
- To find the condition of building
- To obtain critical area of building
- To match with statutory requirement
- To increase the life span of structure.

Reason of Distress in Building

- Distress of building during the service is due to the lack of maintenance of the building which causes deterioration/aging of materials and structural component leading to cracking and corrosion.

- Mostly buildings are not designed for extreme loading condition such as severe earthquake or cyclonic storm, due the extreme loading buildings experience different grade of damage.

- If building is not constructed according to the standard code of practice than it may fail.

- As building codes and byelaws are not followed in design or construction or maintenance therefore, this is the main reason for failure of the buildings during its service life.
- Poor designing of rebar in reinforced concrete structure members and joints.
- Bad workmanship
- Rebar corrosion due to aggressive surrounding.
- Settling or sinking of foundation
- Unexpected extreme loading.

Indian Standard codes and guidelines have stood up to its expectation for achieving safety during previous six earthquakes. Therefore if these codes are not used in designing and construction of building than these buildings are hazardous and dangerous for the residents and surround area.

Bye-Laws

According to clause no. 77 of byelaws the structural audit of building is carried out as follows:

- Age of building between 15 to 30 yrs. - After 5 yrs.
- Age of building greater than 30 yrs. - After 3 yrs.

The periodic building audit is applicable for all except:

- Terraced or linked houses, detached house, semi detached house
- Temporary structures

3.4 SCOPE OF THE STUDY

Inspection consists of following phases:-

- Visit to premises & visual inspection of buildings including structural elements of the building structure.
- Line Diagram of the building floor-wise.
- Lists of tests required to be carried out for preparation of structural drawing with no. of tests & to check health of structure/ building with location on line diagram.
- Preparation & submission of preliminary & final survey/ project report.

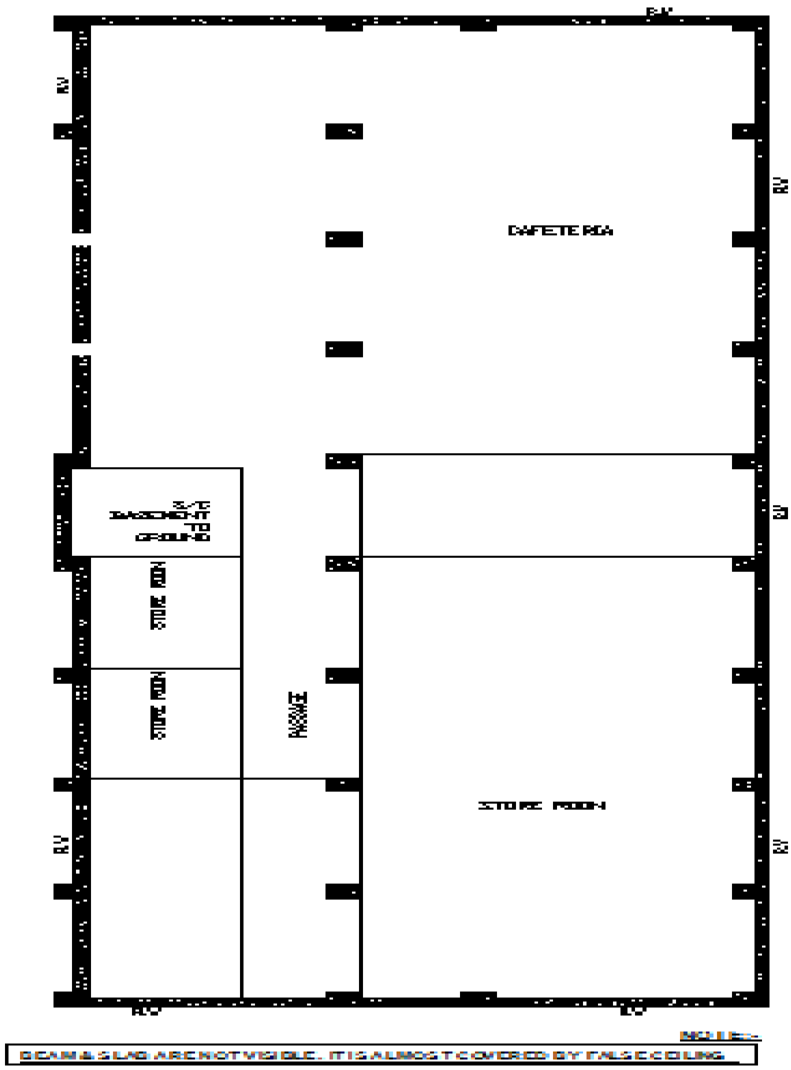
3.5 EXISTING BUILDING DETAILS

3.5.1 General Details of Existing Structure

Name Of Building: -	BSES (BSES Yamuna Power Ltd.) Karkardooma 33KV Grid; Shakti Kiran Building, Karkardooma
Number of Storey: -	B+G+3
Main Use of Building: -	BSES Corporate Office and Power Substation
Age of Existing Str.:-	15-25 Years
Strl System Of existing str. :-	R.C.C Frame Structure.
Soil Condition: -	Typical condition (Info. Not available)

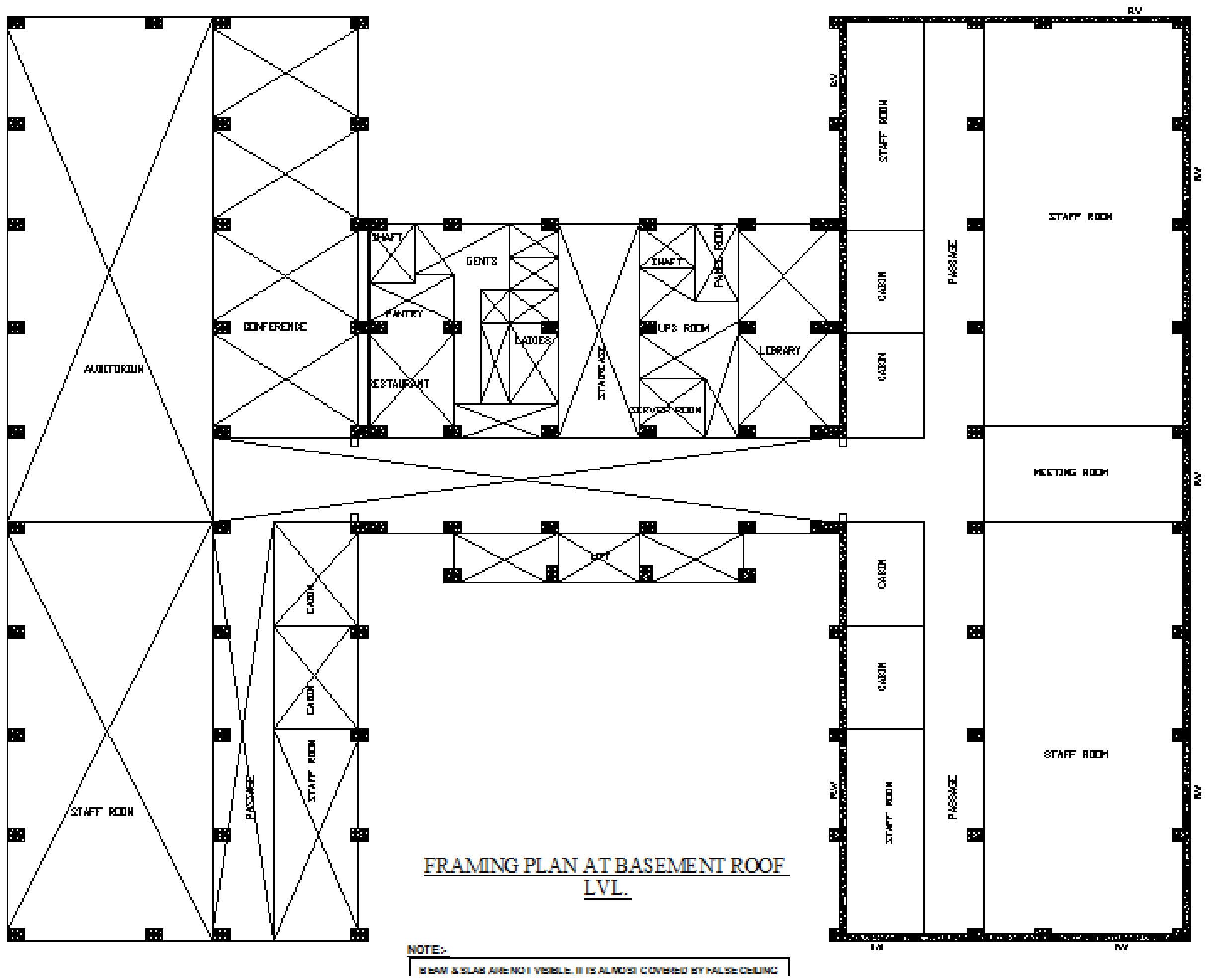
3.5.2 General Arrangement Plan of Existing Structure

BASEMENT

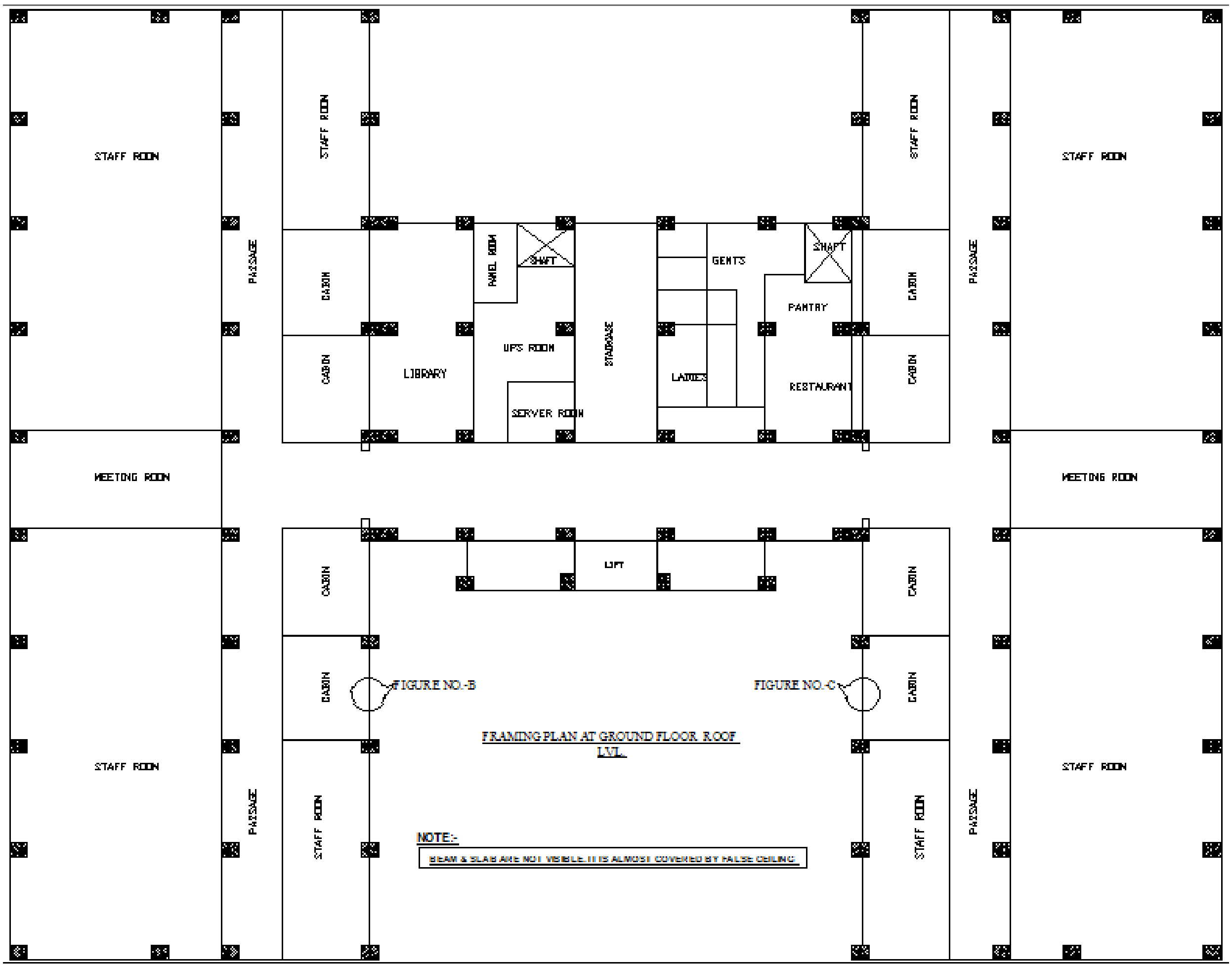


PLAN AT BASEMENT LEVEL

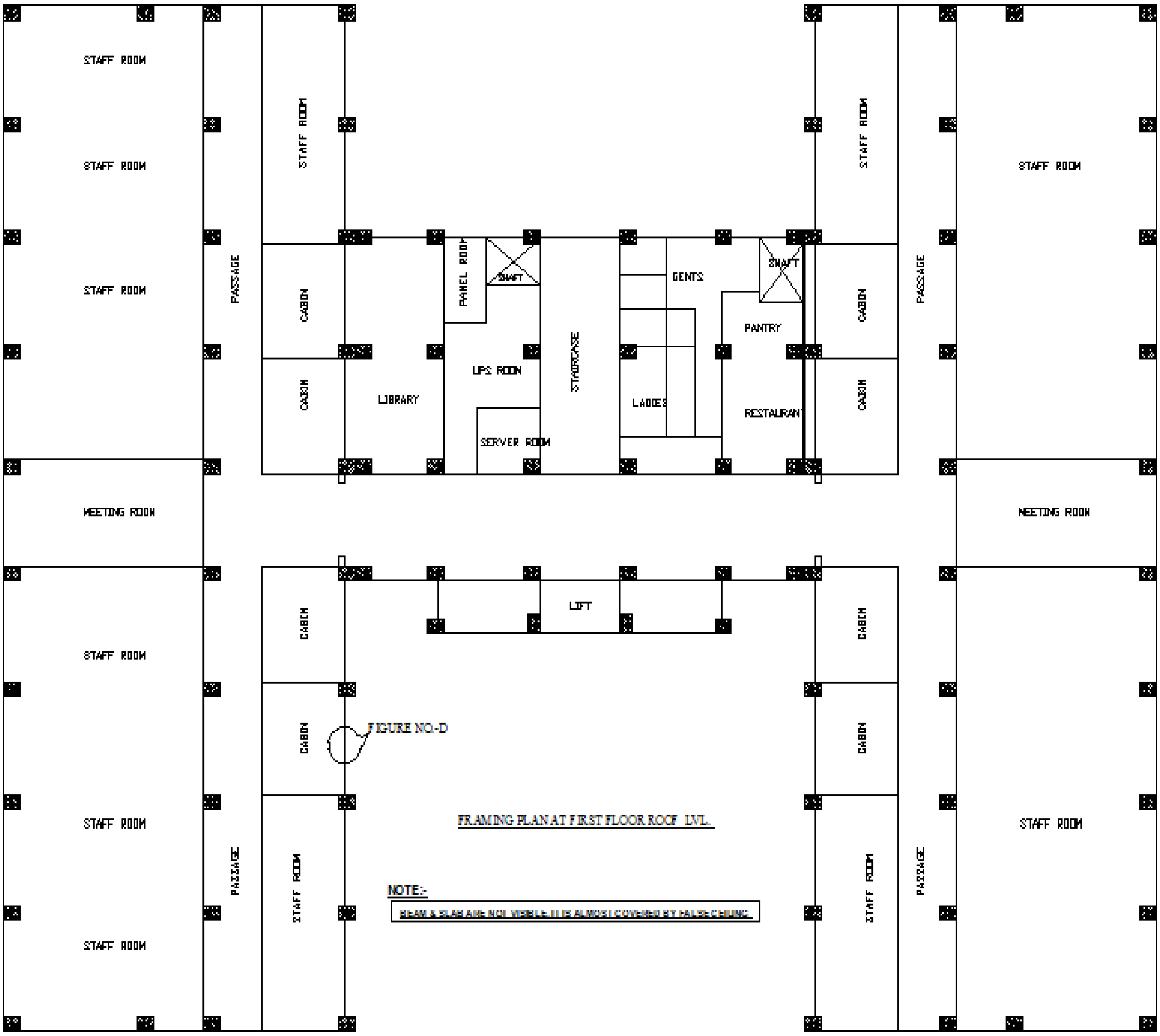
GROUND FLOOR PLAN



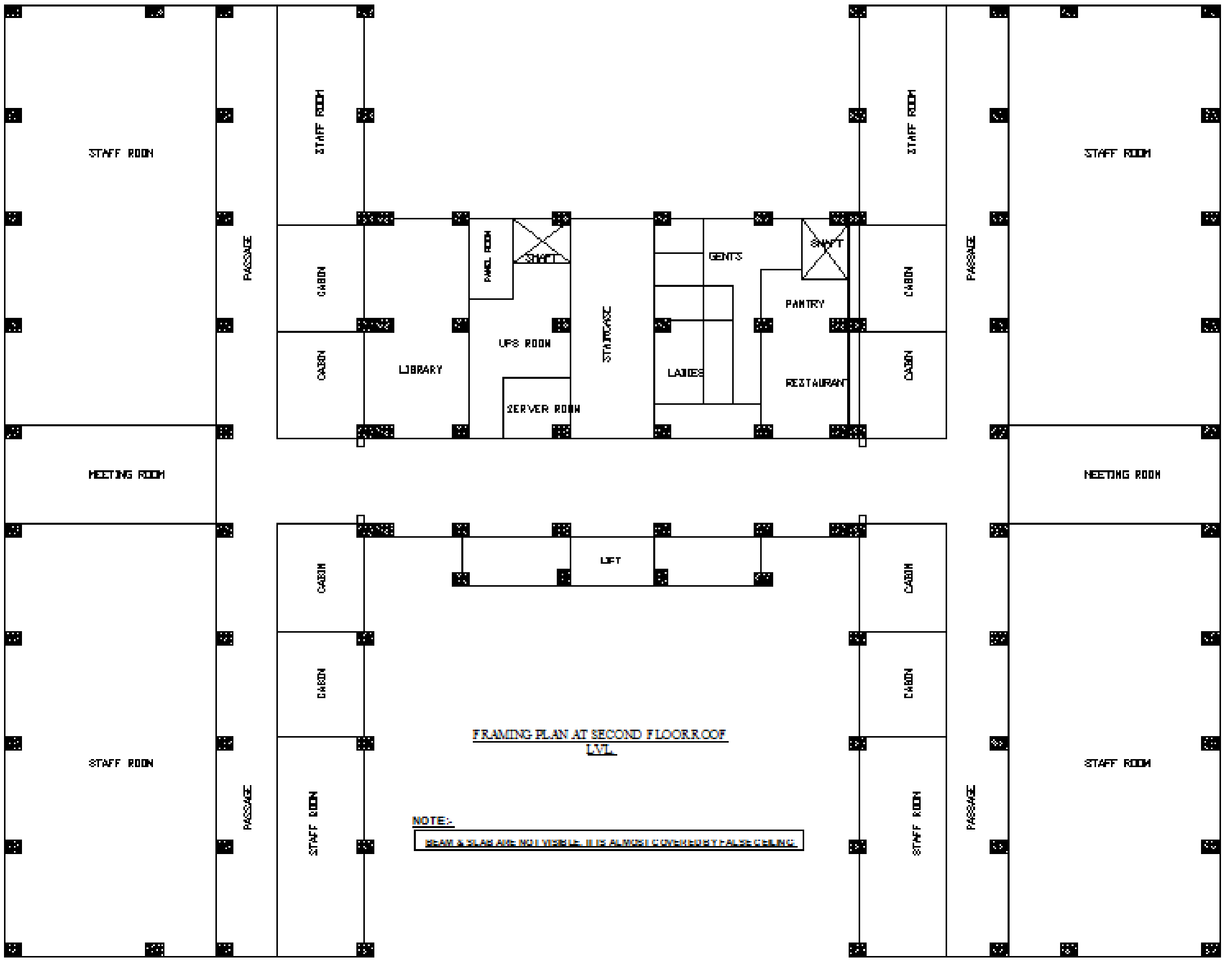
FIRST FLOOR PLAN



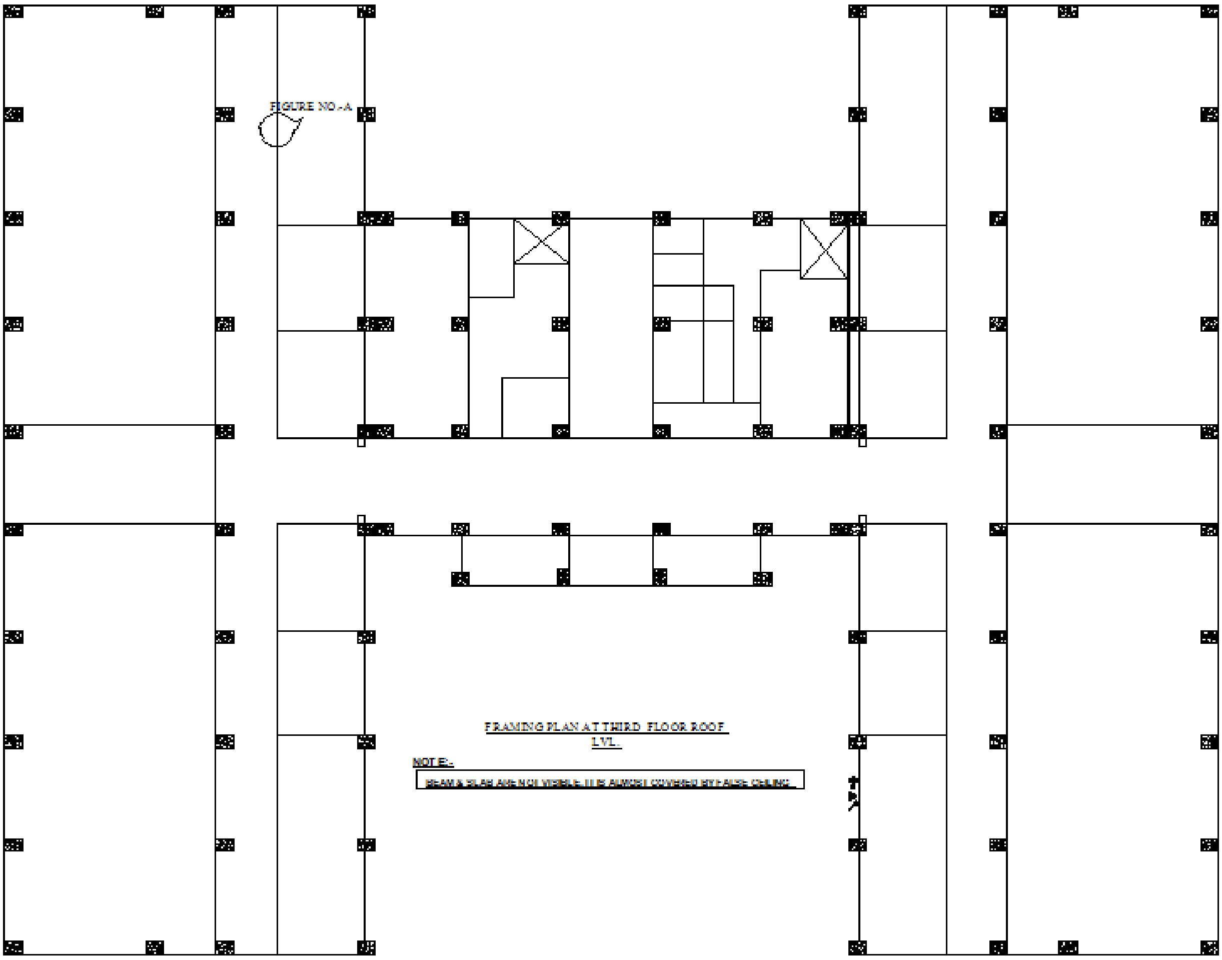
SECOND FLOOR PLAN



THIRD FLOOR PLAN



TERRACE FLOOR PLAN



3.6 Evaluation of structure for repair and up gradation

3.6.1 Evaluation of structure

Main purpose of evaluation of a structure is to place the structure into one of the three categories mentioned below:-

A. Serviceable Building

B. Minor defect in building at certain location which can be repaired at any stage according to the code of practice.

C. Dangerous Buildings which require urgent demolishing.

Steps involved in Condition Evaluation of building are:-

- Degree of Damage and cause of damage (Records mentioned in images attached in below pages).
- To evaluate degree of distress and to estimate the remaining strength of the structure units.
- To design the rehabilitation and retrofitting program of the building.

3.6.2 Steps of Structural Audit

Analysing the Structural and architectural drawings, design calculation, design criteria, structural safety certificate of the structures. In this case (Shakti Kiran Building), accessed the Architectural drawings, but not the structural drawings.

3.6.3 Visual Inspection

Visual inspection has been done, the need of that is mentioned below –

1. It is needed to find the type of structural defect,
2. To identify any short of material deterioration
3. To find any signs of structural distress and deformation
4. To find any structural misuse, this leads to increases structural dead load.

This inspection report will show the following points along with photograph and sketches.

Structural System of the building

Sub structure	:	Not in our scope
Super structure	:	Framing System of structure – R.C Frame/ Load bearing structure – Brick walls/ Any other Structural System
Materials used	:	Concrete in Frame Structure and Solid Brick work in partition / Brick walls- external, internal
Condition of rusting of exposed reinforcement and its extent	:	Condition of reinforcement in external & internal columns, beams etc.

3.6.4 Destructive and Non Destructive Testing:

After the visual inspection to find the real strength and quality of structure non destructive tests is carried out. A number of NDT test is available to find the quality and strength of concrete. Some of this test is very useful in analysing the damage to RCC structure subjected to corrosion.

Strength of concrete

- Rebound Hammer: To find surface hardness of concrete.
- Ultrasonic pulse velocity test : Strength of concrete and homogeneity
- Core sampling and testing : Strength and density of concrete.

Chemical Attack

- Carbonation test : To find depth of carbonation and pH of concrete
- Chloride Test : To find water/acid soluble chloride content
- Sulphate Test : To find the sulphate content of concrete

Corrosion Potential assessment

- Cover Meter Test
- Half Cell Method
- Permeability Test

Homogeneity and integrity Evaluation

Ultrasonic pulse velocity Test

Pushover Analysis

It is used to understand the seismic and gravity loading existing capacity of the structure, which will determine the occupancy level, life safety and collapse prevention. The seismic capacity of existing structure is compared with the potential earthquake which cause risk to the building and human safety.

3.6.5 Observations at Present Site

Visual Inspection of the site was conducted on 13th June 2017. Based on the visit to the said premises and the data was collected regarding details of the building , visual inspection of damage and distress in different building component. The building is categorized under category type A.

No visual sign of distress was seen in building so it can be said that the building satisfies serviceability and safety standard as per standard code of practice therefore no action needed for retrofitting. But further on, to certify the building, we need to conduct a set of test as there is no access to structural drawings and as per norms, we need to perform some tests to provide certification. Tests are proposed to be done in two phases elaborated later in the study.

Visible distress determining the safety of building at our site are:

Status of building in totality:

The building is seems to be ok as per visual inspection and no signs of distress are found but to certify, we need to perform the test to measure the building as per current standards and codes. The NDT result will give the clear picture regarding the status of any internal distress to full fill the safety requirement and degree of performance set by the designer. Only some cracks in the plaster have been found.

Structural Member's status:

Columns – Seems ok visually.

Beam – Seems OK visually, at many areas beams are covered with false ceiling, hence, the condition will be known on structural testing.

Addition or Alterations in the building:

No information is available regarding any addition and alteration of building at a later date.

Dampness and leakages:

On visual inspection, it has been found that there is water accumulation on terrace. In spite of this, there are no visible signs of any signage below the top floor slab (this cannot be corroborated completely, as the slab soffit is not visible because of false ceiling). However, the water accumulation on terrace needs to be taken care of immediately.

Note:- Building were almost covered by False ceiling and hence visual inspection for beam and slab were not carried out thoroughly, same as for columns as almost columns were covered up-to 1m above floor level hence columns were inspected above that.

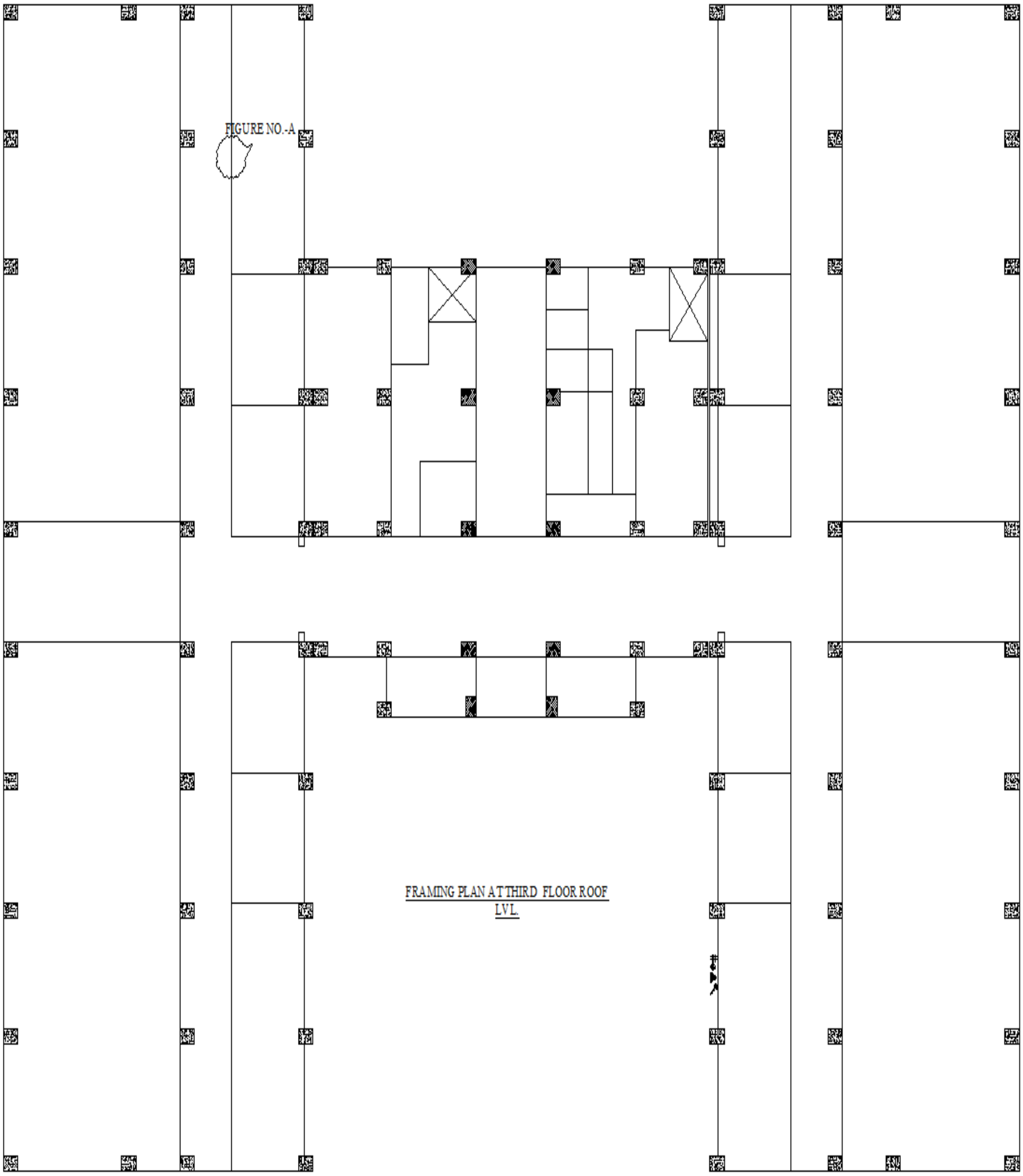
Fig. 8(a):- Showing water leakage at terrace

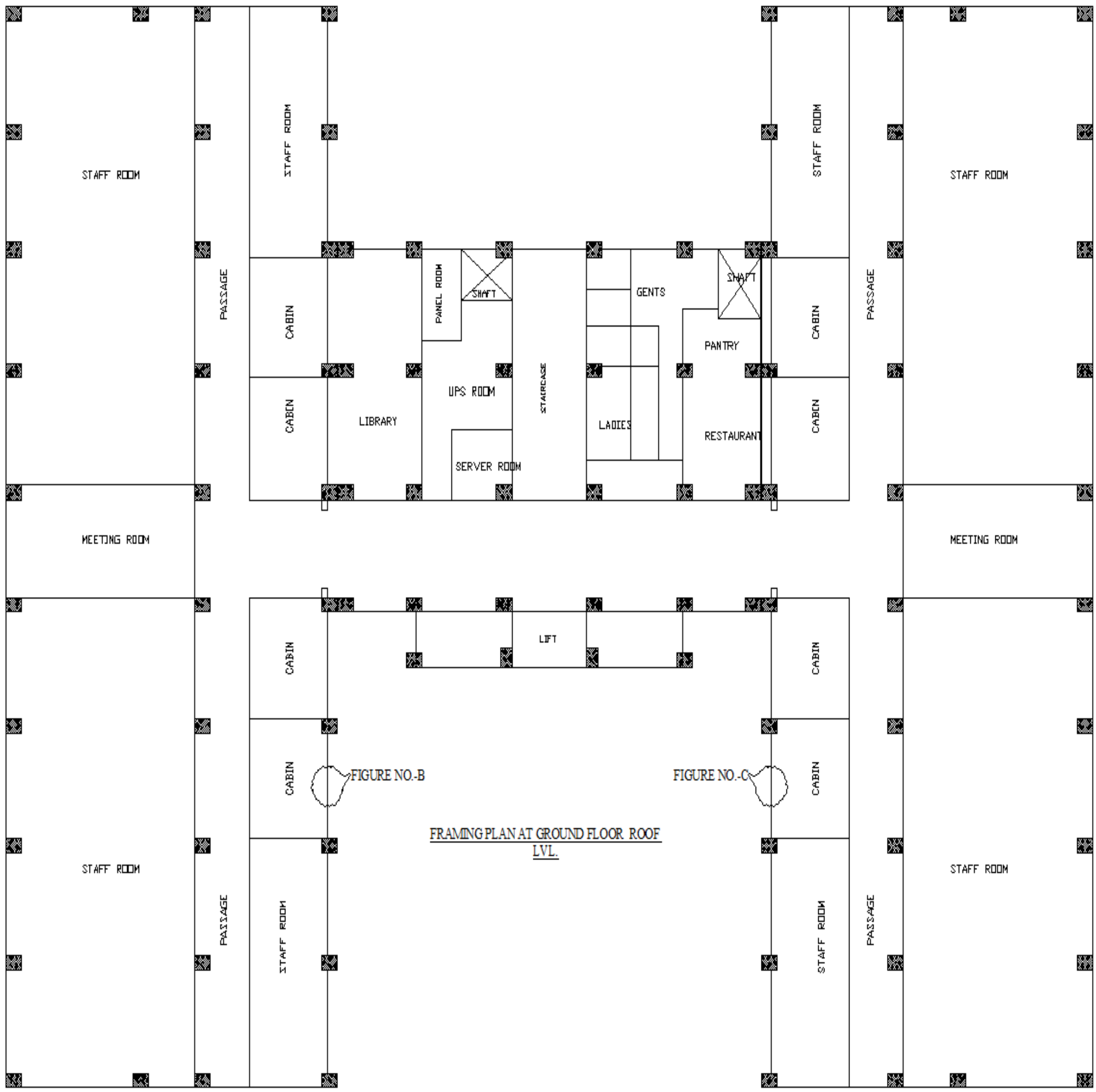
Fig. 8(b) Showing Cracks in plaster with some swelling

Fig.8(c):- Showing Cracks in plaster and probably in beam

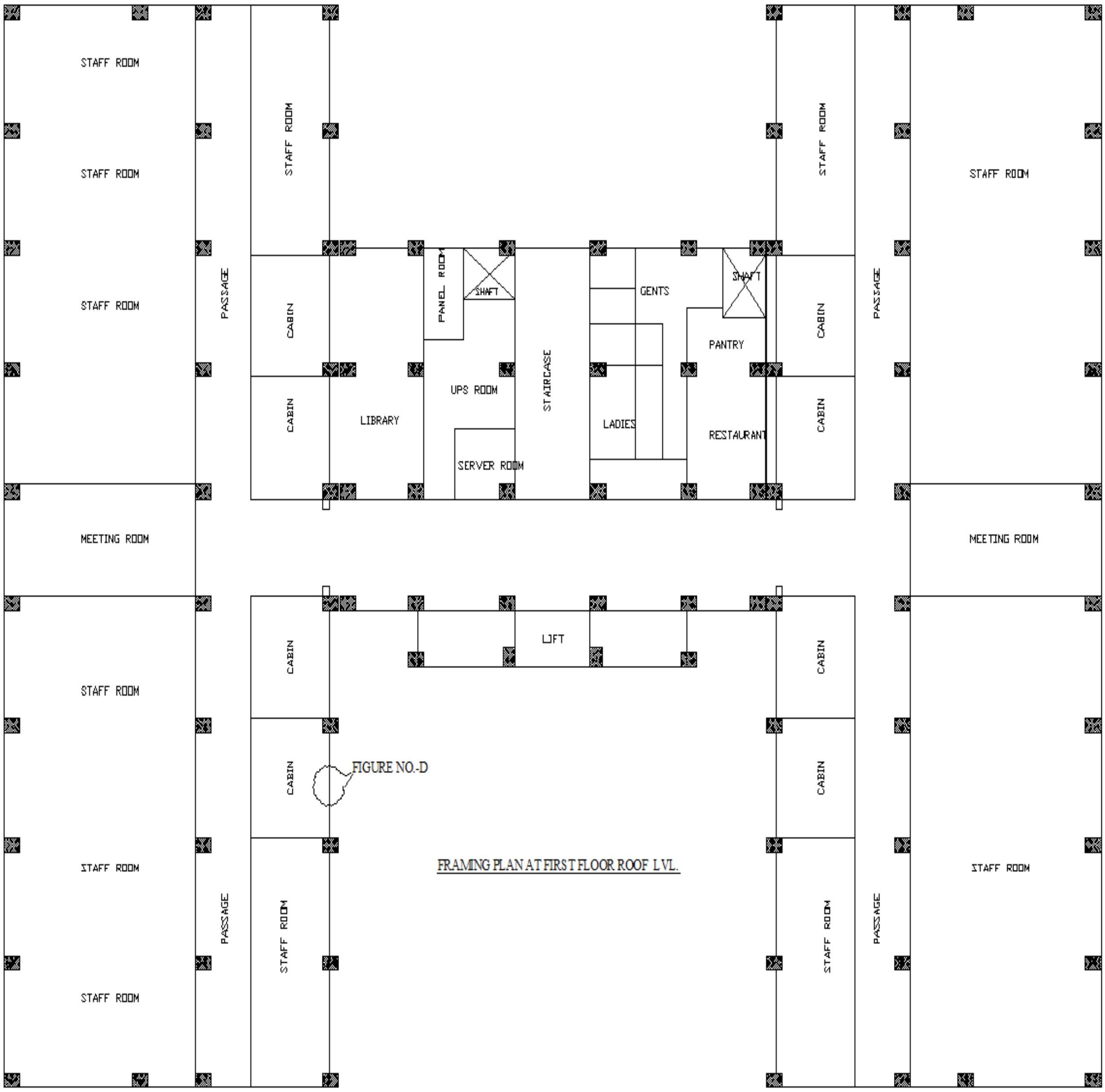
Fig. 8(d):- Showing Cracks in plaster and probably in beam

LOCATION SHOWING DISTRESS





FRAMING PLAN AT GROUND FLOOR ROOF LVL.


STAFF ROOM
STAFF ROOM
STAFF ROOM
PASSAGE
STAFF ROOM
CABIN
CABIN
LIBRARY
PANEL ROOM
SHAFT
UPS ROOM
SERVER ROOM
STAIRCASE
GENTS
LADIES
SHAFT
PANTRY
RESTAURANT
CABIN
CABIN
STAFF ROOM
PASSAGE
STAFF ROOM
MEETING ROOM
MEETING ROOM
LIFT
CABIN
CABIN
FIGURE NO.-D
STAFF ROOM
STAFF ROOM
PASSAGE
STAFF ROOM
FRAMING PLAN AT FIRST FLOOR ROOF LVL.
CABIN
CABIN
STAFF ROOM
PASSAGE
STAFF ROOM

3.6.6 Analysis of Present Site

As the structural drawing of the building and details of the structural system including the material used and its foundation details are not available hence detail investigation has to be conducted. To note the dimension of the structural elements measurement has to be conducted at site. Through NDT testing property of structural material like steel reinforcement, concrete and masonry quality must be ascertained in field or in laboratory from collected sample from site. Through geotechnical technique characteristic of soil has to be obtained. The above details are necessary for evaluating safety of the structure and recommending the retrofitting or strengthening measures.

The building seems to be ok as per visual inspection and no signs of distress are found but to certify, we need to perform a minimum no. of tests to measure/ test the building. The NDT result will give the clear picture regarding the status of any internal distress to satisfy the performance criteria set by the user, which, in the case of present site should be conformance to the BIS standard established in 2002 for earthquake safety with reasonable level of variation on account of decay/ deterioration due to the passage of time.

The tests as recommended in Phase II are proposed to be conducted, only in case of at least 20% of the tests fail the stipulated requirements as set for Phase I tests.

We are recommending performing tests at Ground floor and Terrace Floor level only in Phase-1 as building is in good condition.

NDT MARKING (PHASE-I)

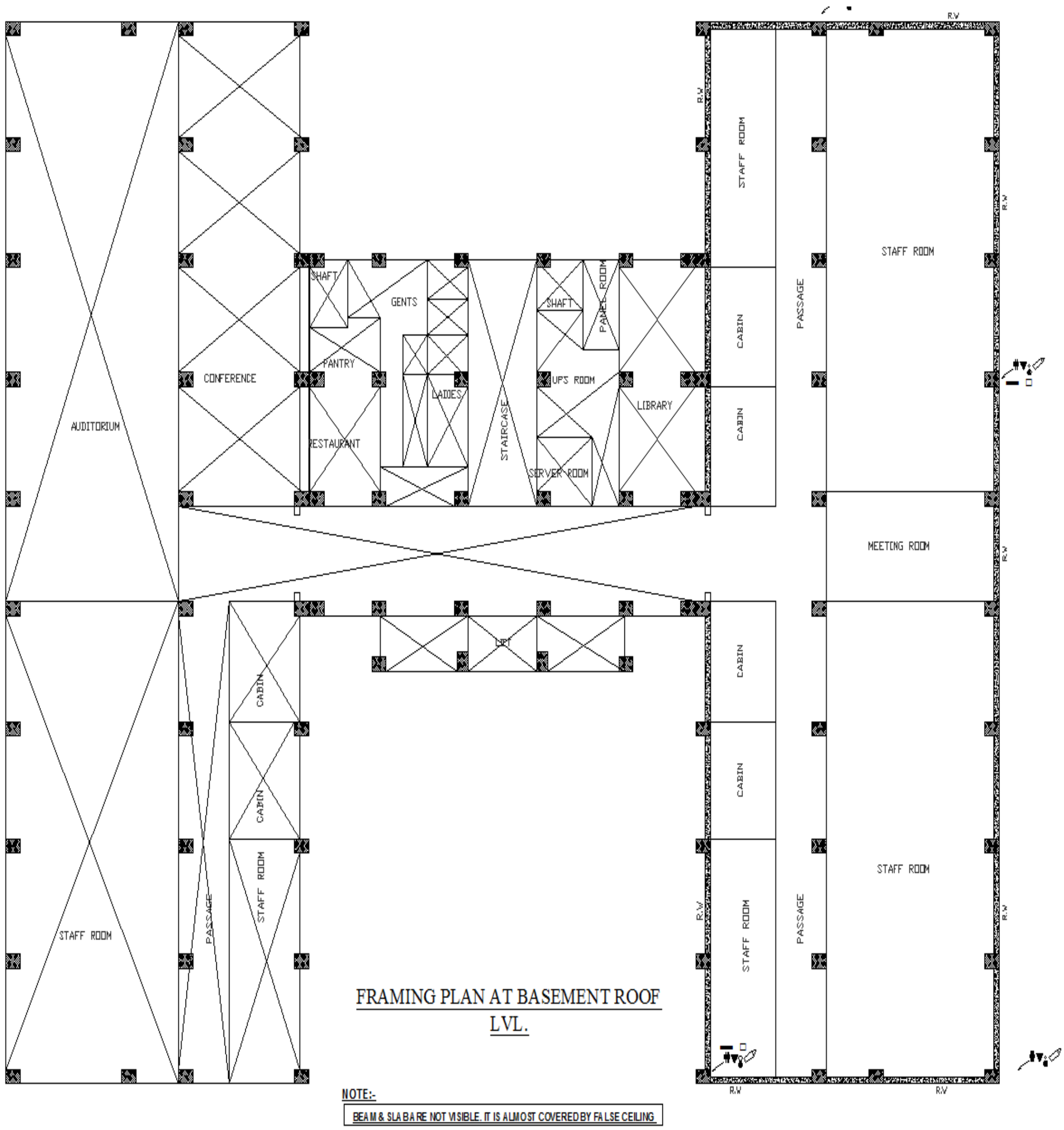


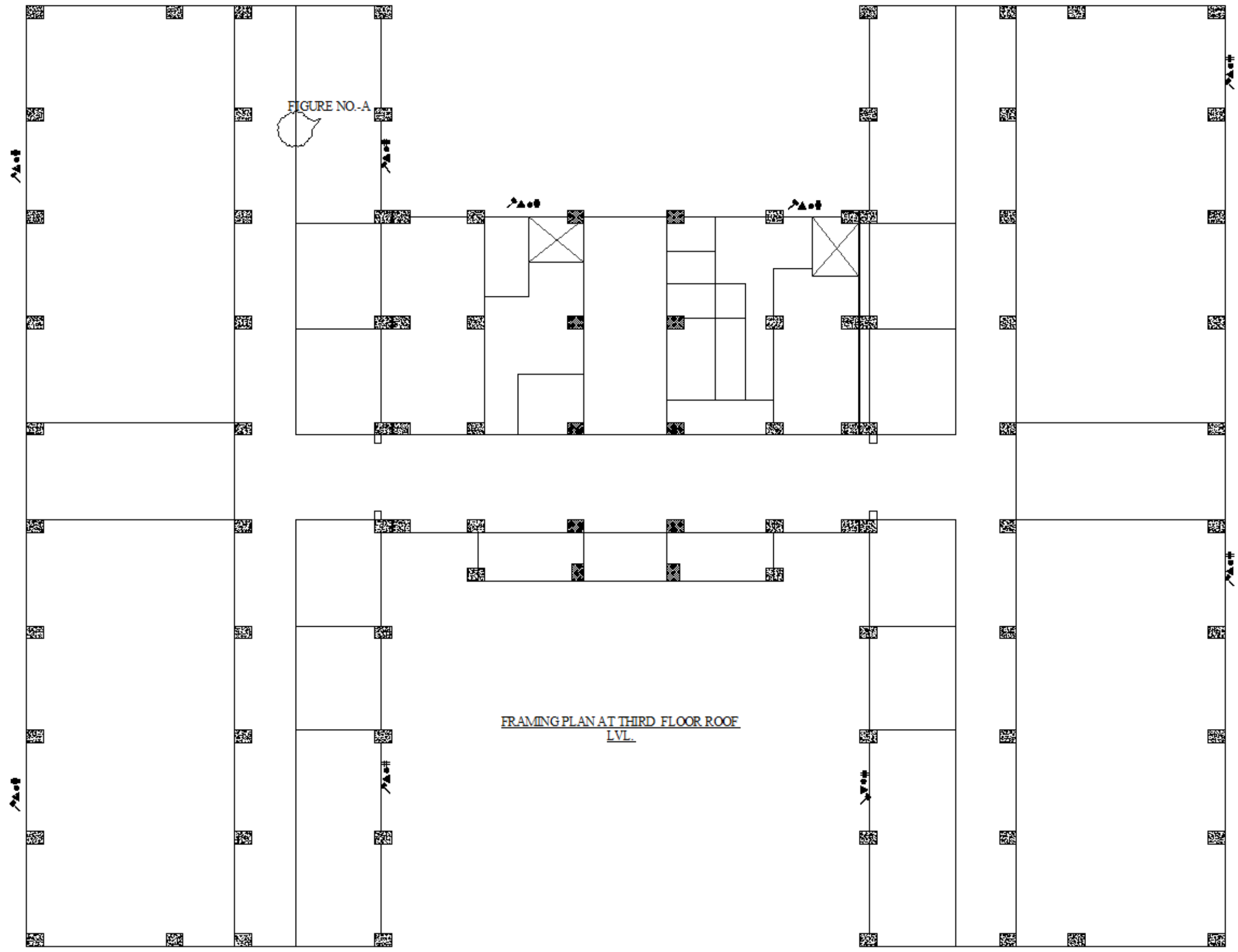
Table 5:- Conducting Schedule

CONDUCTING SCHEDULE			
S.NO	DESRIPTION OF TEST	Nos.	SYMBOL
1	Schmidt's rebound hammer test for determining the concrete compressive strength	0	▲
2	Ultrasound pulse velocity tests for establishing the quality of concrete	4	⬬
3	Taking out concrete cores,preparing specimen for lab testing , performance lab test for compressive strength	2	□
4	Reber locator tests for locating rebars and or determining rebar dia (whenever possible) and rebar spacing.	4	#
5	Carbonation tests for determining depth of carbonate of concrete.	4	▼
6	Half-cell potential test	4	⬭
7	Chloride and sulphate content	0	▬
8	Lateral resistance test for brick	0	+
9	Compressive strength of wall	0	@

Table 6:- Physical Exploration

PHYSICAL EXPLORATION			
S.NO	DESRIPTION OF TEST	Nos.	Symbol
1	Beam cover breaking to see R/F	0	
2	Col. Cover breaking to see R/F	4	
3	Slab cover breaking	0	
4	Exposing Foundation to see extent	0	
5	Foundation cover to see R/F	0	

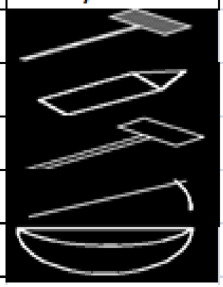
TERRACE.



CONDUCTING SCHEDULE

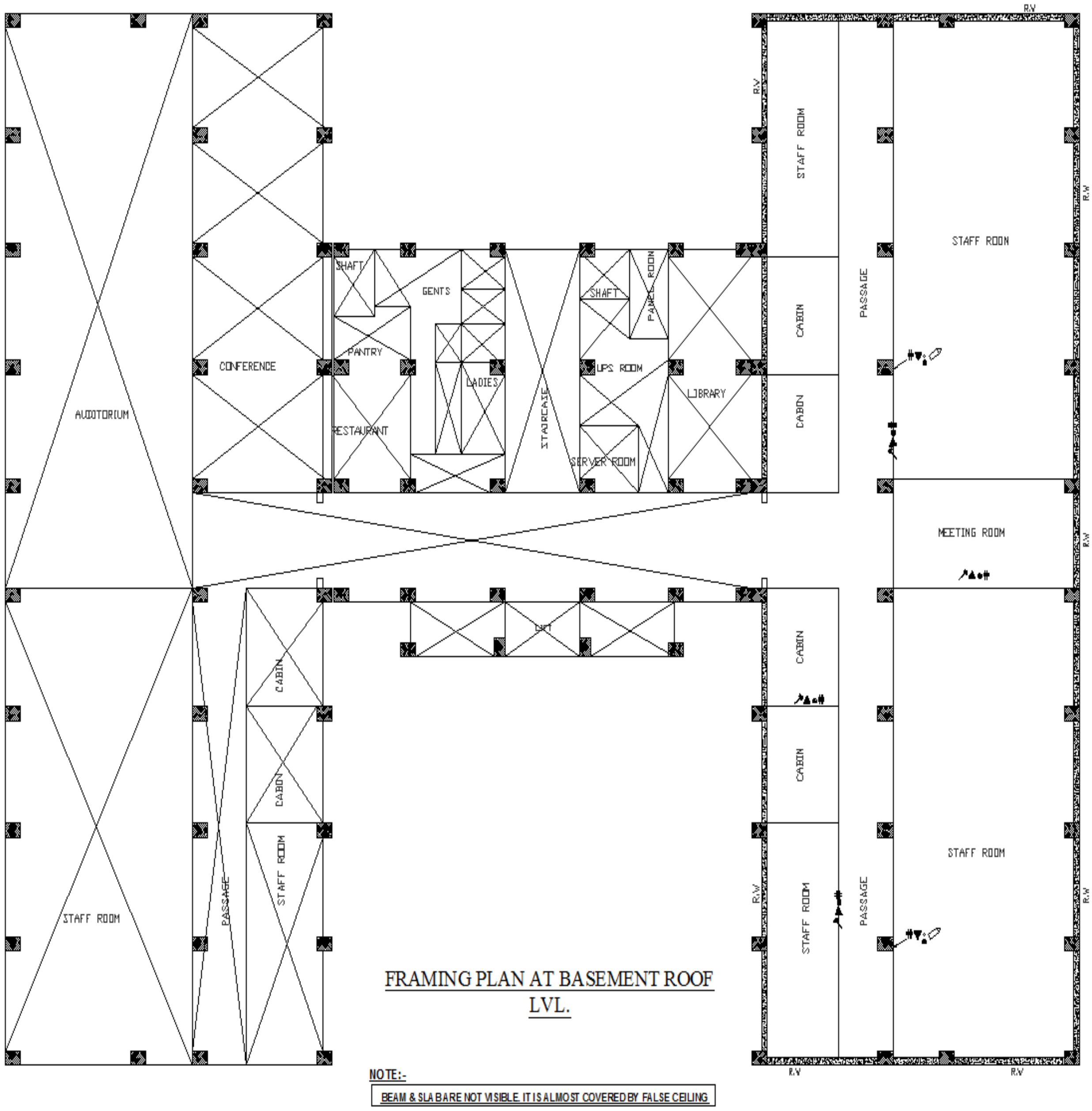
S.NO	DESRIPTION OF TEST	Nos.	SYMBOL
1	Schmidt's rebound hammer test for determining the concrete compressive strength	9	▲
2	Ultrasound pulse velocity tests for establishing the quality of concrete	9	⬬
3	Taking out concrete cores,preparing specimen for lab testing , performance lab test for compressive strength	0	□
4	Reber locator tests for locating rebars and or determining rebar dia (whenever possible) and rebar spacing.	9	#
5	Carbonation tests for determining depth of carbonate of concrete.	0	▼
6	Half-cell potential test	0	⬭
7	Chloride and sulphate content	0	▬
8	Lateral resistance test for brick	0	+
9	Compressive strength of wall	0	@

PHYSICAL EXPLORATION

S.NO	DESRIPTION OF TEST	Nos.	Symbol
1	Beam cover breaking to see R/F	9	
2	Col. Cover breaking to see R/F	0	
3	Slab cover breaking	0	
4	Exposing Foundation to see extent	0	
5	Foundation cover to see R/F	0	

NDT TECHNIQUES- (PHASE-2)

NDT Marking Plan at all floor levels. (BASEMENT FLOOR ROOF LVL.)

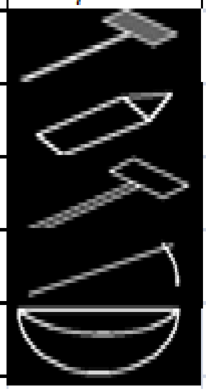


CONDUCTING SCHEDULE

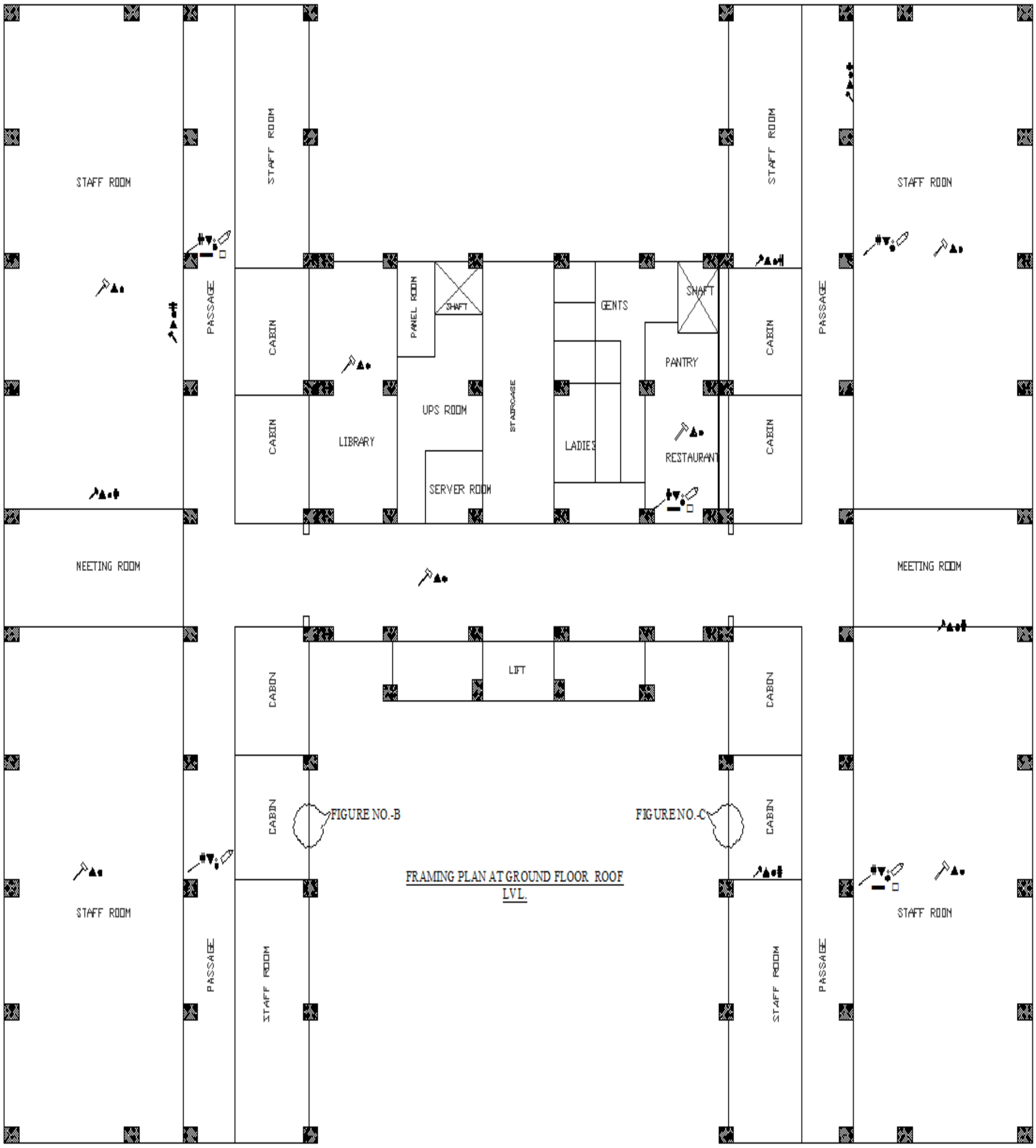
S.NO	DESRIPTION OF TEST	Nos.	SYMBOL
1	Schmidt's rebound hammer test for determining the concrete compressive strength	4	▲
2	Ultrasound pulse velocity tests for establishing the quality of concrete	6	⬬
3	Taking out concrete cores,preparing specimen for lab testing , performance lab test for compressive strength	0	□
4	Reber locator tests for locating rebars and or determining rebar dia (whenever possible) and rebar spacing.	6	#
5	Carbonation tests for determining depth of carbonate of concrete.	2	▼
6	Half-cell potential test	2	⬭
7	Chloride and sulphate content	0	▬
8	Lateral resistance test for brick	0	+
9	Compressive strength of wall	0	@

PHYSICAL EXPLORATION

S.NO	DESRIPTION OF TEST	Nos.	Symbol
1	Beam cover breaking to see R/F	4	
2	Col. Cover breaking to see R/F	2	
3	Slab cover breaking	0	
4	Exposing Foundation to see	0	
5	Foundation cover to see R/F	0	



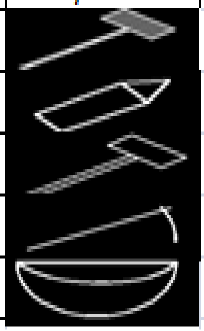
Ground floor roof level.



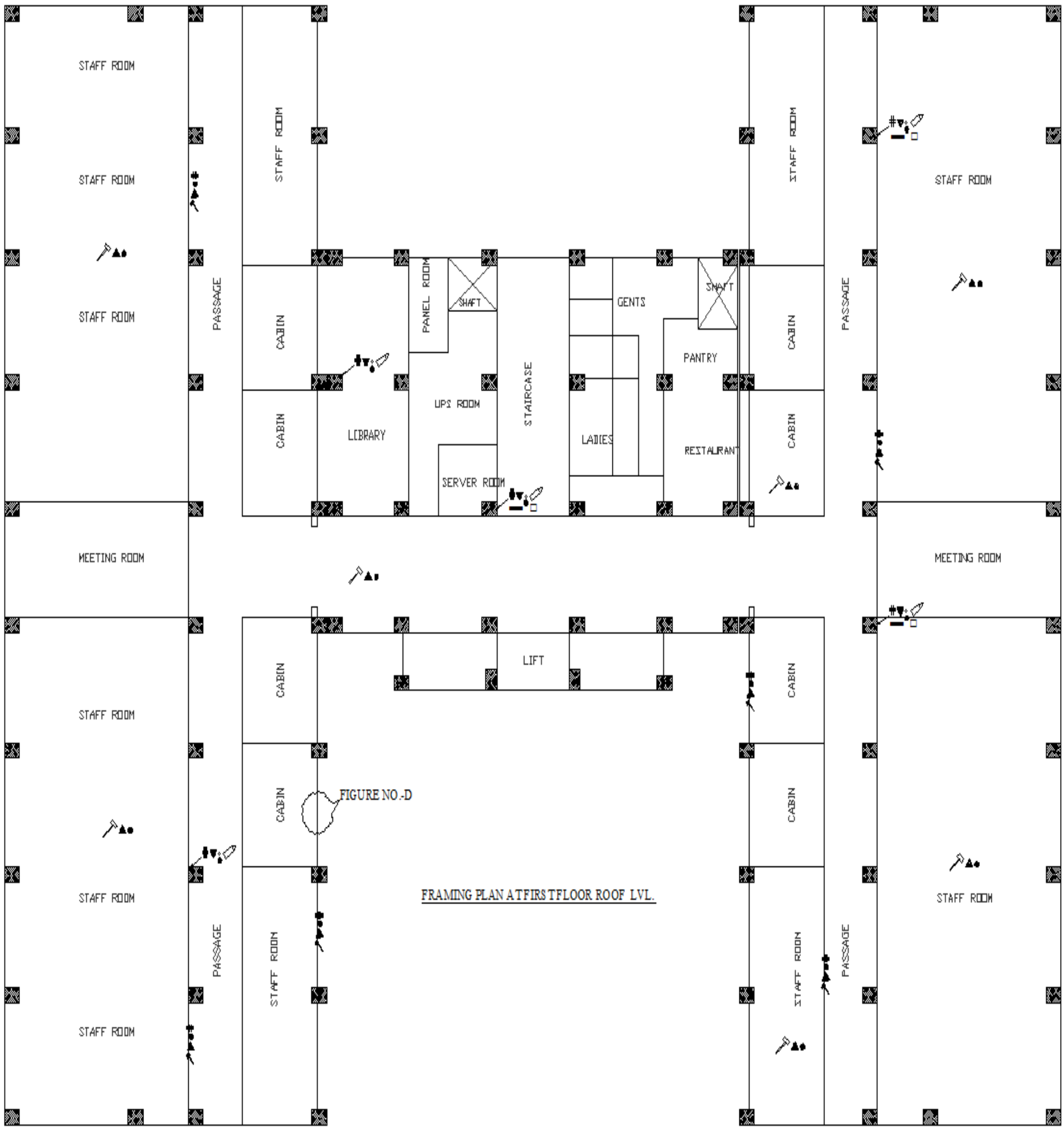
CONDUCTING SCHEDULE

S.NO	DESRIPTION OF TEST	Nos.	SYMBOL
1	Schmidt's rebound hammer test for determining the concrete compressive strength	13	▲
2	Ultrasound pulse velocity tests for establishing the quality of concrete	18	●
3	Taking out concrete cores,preparing specimen for lab testing , performance lab test for compressive strength	3	□
4	Reber locator tests for locating rebars and or determining rebar dia (whenever possible) and rebar spacing.	11	#
5	Carbonation tests for determining depth of carbonate of concrete.	5	▼
6	Half-cell potential test	5	⬭
7	Chloride and sulphate content	3	▬
8	Lateral resistance test for brick	0	+
9	Compressive strength of wall	0	@

PHYSICAL EXPLORATION

S.NO	DESRIPTION OF TEST	Nos.	Symbol
1	Beam cover breaking to see R/F	6	
2	Col. Cover breaking to see R/F	5	
3	Slab cover breaking	0	
4	Exposing Foundation to see	0	
5	Foundation cover to see R/F	0	

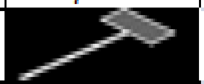
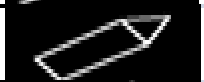
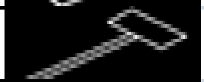
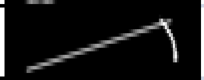
First floor roof lvl.



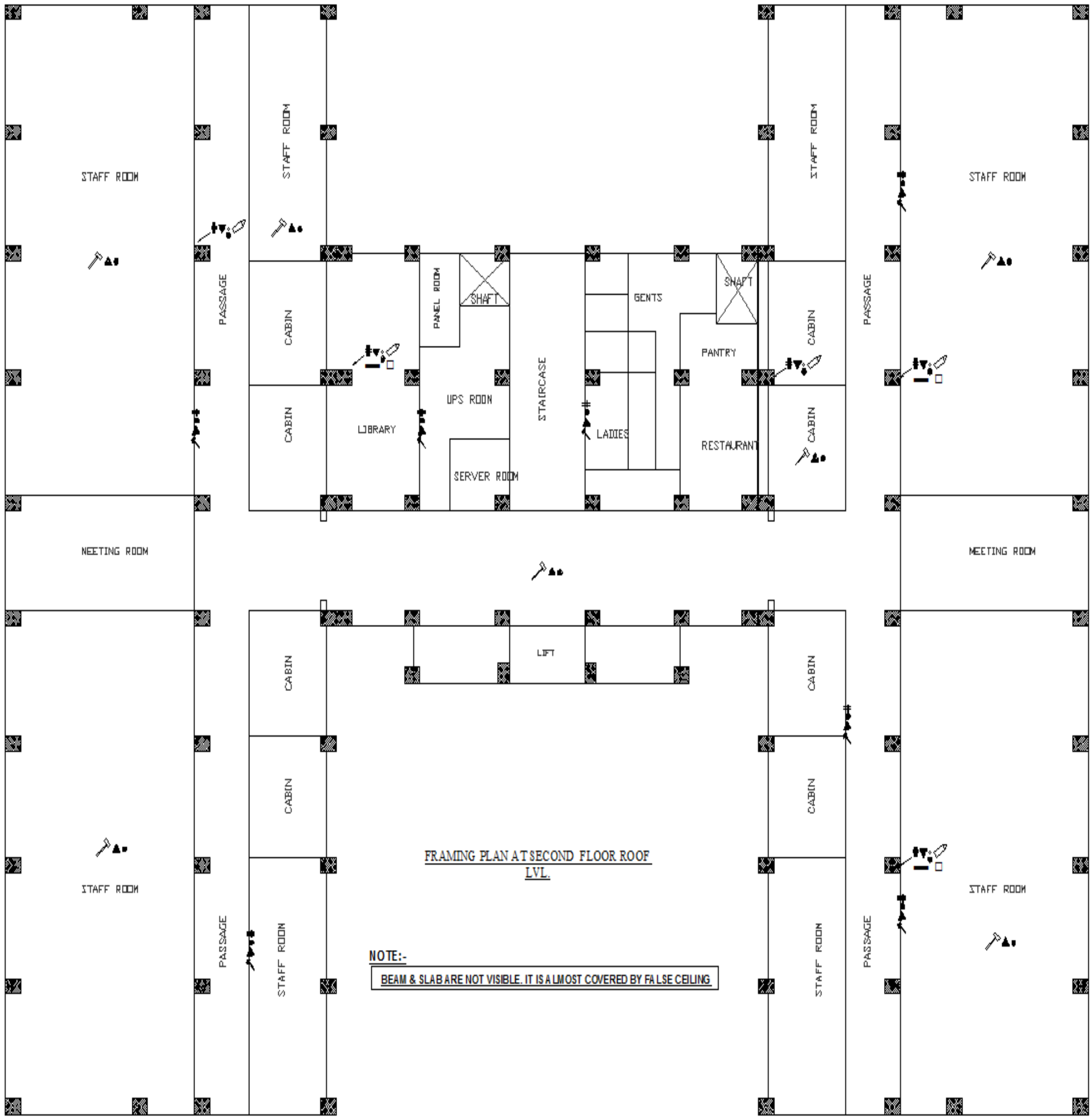
CONDUCTING SCHEDULE

S.NO	DESRIPTION OF TEST	Nos.	SYMBOL
1	Schmidt's rebound hammer test for determining the concrete compressive strength	13	▲
2	Ultrasound pulse velocity tests for establishing the quality of concrete	18	●
3	Taking out concrete cores,preparing specimen for lab testing , performance lab test for compressive strength	3	□
4	Reber locator tests for locating rebars and or determining rebar dia (whenever possible) and rebar spacing.	11	#
5	Carbonation tests for determining depth of carbonate of concrete.	5	▼
6	Half-cell potential test	5	○
7	Chloride and sulphate content	3	▬
8	Lateral resistance test for brick	0	+
9	Compressive strength of wall	0	@

PHYSICAL EXPLORATION

S.NO	DESRIPTION OF TEST	Nos.	Symbol
1	Beam cover breaking to see R/F	6	
2	Col. Cover breaking to see R/F	5	
3	Slab cover breaking	0	
4	Exposing Foundation to see	0	
5	Foundation cover to see R/F	0	

Second floor roof lvl.

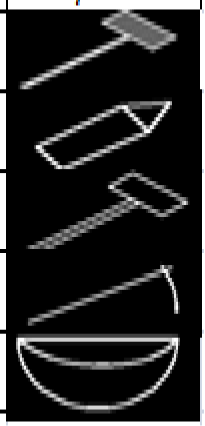


CONDUCTING SCHEDULE

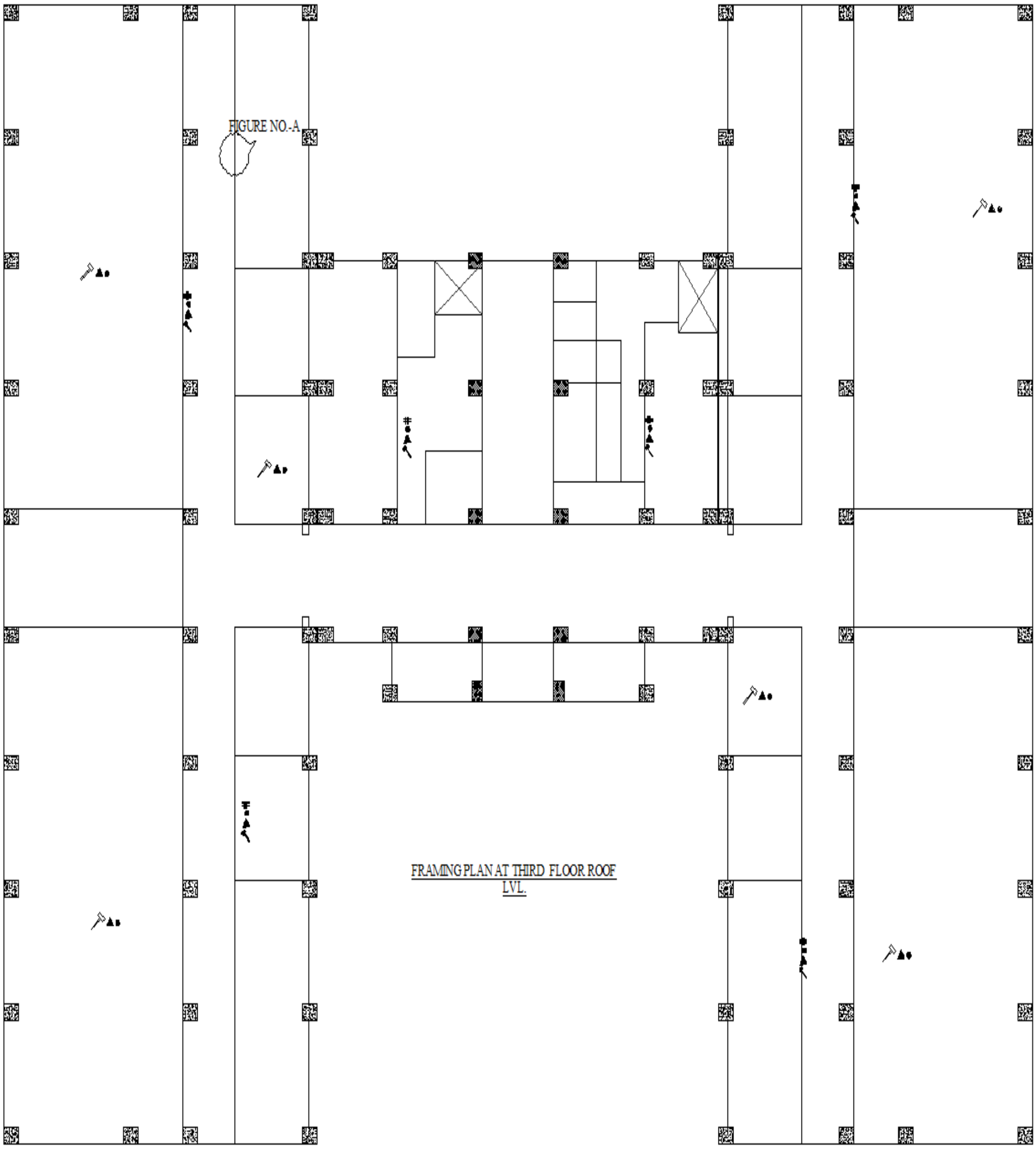
S.NO	DESRIPTION OF TEST	Nos.	SYMBOL
1	Schmidt's rebound hammer test for determining the concrete compressive strength	14	▲
2	Ultrasound pulse velocity tests for establishing the quality of concrete	19	⬬
3	Taking out concrete cores,preparing specimen for lab testing , performance lab test for compressive strength	3	□
4	Reber locator tests for locating rebars and or determining rebar dia (whenever possible) and rebar spacing.	12	#
5	Carbonation tests for determining depth of carbonate of concrete.	5	▼
6	Half-cell potential test	5	⬭
7	Chloride and sulphate content	3	▬
8	Lateral resistance test for brick	0	+
9	Compressive strength of wall	0	@

PHYSICAL EXPLORATION

S.NO	DESRIPTION OF TEST	Nos.	Symbol
1	Beam cover breaking to see R/F	7	
2	Col. Cover breaking to see R/F	5	
3	Slab cover breaking	0	
4	Exposing Foundation to see	0	
5	Foundation cover to see R/F	0	



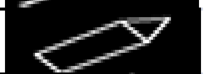
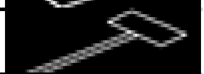
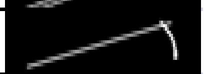
Terrace



CONDUCTING SCHEDULE

S.NO	DESRIPTION OF TEST	Nos.	SYMBOL
1	Schmidt's rebound hammer test for determining the concrete compressive strength	12	▲
2	Ultrasound pulse velocity tests for establishing the quality of concrete	12	⬬
3	Taking out concrete cores,preparing specimen for lab testing , performance lab test for compressive strength	0	□
4	Reber locator tests for locating rebars and or determining rebar dia (whenever possible) and rebar spacing.	6	#
5	Carbonation tests for determining depth of carbonate of concrete.	0	▼
6	Half-cell potential test	0	⬭
7	Chloride and sulphate content	0	▬
8	Lateral resistance test for brick	0	+
9	Compressive strength of wall	0	@

PHYSICAL EXPLORATION

S.NO	DESRIPTION OF TEST	Nos.	Symbol
1	Beam cover breaking to see R/F	6	
2	Col. Cover breaking to see R/F	0	
3	Slab cover breaking	0	
4	Exposing Foundation to see	0	
5	Foundation cover to see R/F	0	

CHAPTER 4: CONCLUSION AND REMARKS

1) This report high light the importance of condition assessment and evaluation of safety of existing building in risk prone zone . Through this evaluation designing and implementation of retrofitting or strengthen of structure to satisfy the safety and performance according to building by laws.

2) The condition of the building is being decided based on the NDMA guide lines for retrofitting of existing structure and FEMA 356 Guidelines, FEMA stands for Federal Emergency Management Agency which actually does the "SEISMIC REHABILITATION OF BUILDINGS".

3) The building seems to be ok as per visual inspection and no signs of distress are found but in order to provide certification of stability, we need to perform a minimum number of tests to measure/ test the building structural elements. The Non-destructive Tests (NDT) result will give the clear picture regarding the status of any internal distress to satisfy the performance criteria set by the user, which, in the case of present site should be conformance to the codes established in 1998 with reasonable level of variation on account of decay/ deterioration due to the passage of time.

4) Based on visual inspection and test reports of phase 1 testing, if reports are found to be fulfilling the satisfactory condition criteria , I,e if tests of pahse-1 is not coming up to the mark or more than 20% of results are failing then there is need to conduct phase 2 NDT tests.

5) Below tables provide a list of the tests types and likely no. required floor-wise as well as for the entire premises. Based on experience, it can be said that a variation of upto ±5% is expected in the total no. of tests

4.1 Further Scope of Study

The report concludes on high lighting the most critical area which require immediate repair and retrofitting. For ex:- no. of column , Slabs, beams and other structural element need immediate repair and strengthening.

It is observed that the NDT method and detail inspection has very important role in condition evaluation of existing structure. A great expertise is needed to interpret the data collected from field and test result so that proper evaluation of the condition of safety can be ascertained.

Photographs of Site


G.A-34


CS250D5P
Cummins

This Portion requires re-construction can’t be repaired

This Portion requires re-construction can’t be repaired

This Portion requires re-construction can't be repaired

This Portion requires re-construction can’t be repaired

This Portion requires re-construction can’t be repaired

This Portion requires re-construction can’t be repaired

REFERENCES

1. “RAPID VISUAL SCREENING OF BUILDINGS FOR POTENTIAL SEISMIC HAZARDS” a handbook FEMA (Federal Emergency Management Agency) 154, Edition 2/march 2002 U.S Dept. Of Homeland Security.

2. “RAPID VISUAL SCREENING OF BUILDINGS FOR POTENTIAL SEISMIC HAZARDS” supporting documentation FEMA 155, Edition 2 U.S Dept. Of Homeland Security.

3. IS 13935:2009 “Indian standard seismic Evaluation, Repair and strengthening of Masonry Building Guidelines (First Revision)”.

4. Dr. Indrani Gogoi “Rapid visual screening of building in Guwahati City” Department of civil Engineering, NITK Surathkal.

5. Dr Anand S. Arya, “Rapid visual screening of RCC building”
(professor Emeritus, Dept. Of eq. Engineering, IIT Roorkee) chairman, BIS Committee CED 39 National seismic Advisor (EVR) Ministry of home Affairs.

6. Dr Anand S. Arya, “Rapid visual screening of Masonry Buildings” (Professor Emeritus, Dept. Of Eq. Engineering, IIT Roorkee) Chairman, BIS committee CED 39 National seismic Advisor (ERV) Ministry of home Affairs

7. “Integrated Rapid visual screening of Buildings” BIPS(Building and infrastructure protection series)04/ September 2007 U.S. Dept. Of Homeland security

8. “Building design of homeland security” Instructor guide FEMA (risk management series)/ January 2002 U.S. Dept. Of Homeland Security

9. “Periodic structural inspection of existing buildings-Guidelines for structural engineers” Building and construction authority

10. Yumei Wang*1 and Kenneth A. Goettel*2 “Enhanced rapid visual screening(E-RVS) Method for polarization of seismic retrofits in Oregon” 1Oregon Department of Geology and Mineral Industries, 800 NE Oregon St., Suite 965, Portland, Oregon 97232 2 Goettel and associates Inc., 1732 Arena Drive, California, 95616.

11. “Concept of risk and vulnerability studies; Different level of risk assessment” Introduction to Engineering seismology: Lec 17 nptel online lectures

12. Prof. Ravi Sinha and Prof. Alok Goyal “ A National policy of seismic vulnerability assessment of buildings and procedure for the rapid visual screening of buildings for potential seismic vulnerability”